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RESEARCH MEMORANDUM

AERODYNAMIC CHARACTERISTICS OF A 42° SWEEP-BACK WING WITH
ASPECT RATIO 4 AND NACA 64₁-112 AIRFOIL SECTIONS AT
REYNOLDS NUMBERS FROM 1,700,000 TO 9,500,000

By

Robert H. Neely and D. William Conner

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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AERODYNAMIC CHARACTERISTICS OF A 42° SWEEP-BACK WING WITH
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REYNOLDS NUMBERS FROM 1,700,000 TO 9,500,000

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SUMMARY

Wind-tunnel tests were made of a 42° swept-back wing to determine low-speed aerodynamic characteristics in pitch and in yaw at high Reynolds numbers. The characteristics in pitch were obtained over a Reynolds number range from 1,700,000 to 9,500,000 and the characteristics in yaw, from 1,700,000 to 5,300,000. The wing had an aspect ratio of 4, a taper ratio of 0.625, and NACA 64₁-112 airfoil sections normal to the 0.273-chord line.

The wing characteristics at high angles of attack were greatly influenced by Reynolds number in the range from 1,700,000 to 5,300,000 but were little affected in the range from 5,300,000 to 9,500,000. The principal effect of increasing the value of Reynolds number was to delay wing stalling to higher angles of attack. The maximum lift coefficients in the higher range of Reynolds number were about 1.1 without flaps and about 1.3 with half-span split flaps deflected 60° . Abrupt tip stalling caused unstable changes in the pitching moment at maximum lift. The effective dihedral parameter $C_{l\psi}$ varied approximately linearly with lift coefficient at a Reynolds number of 5,300,000 and reached a maximum value near maximum lift of about 0.0040 without flaps and 0.0050 with flaps.

At Reynolds numbers greater than 1,700,000 roughness in the form of carborundum grains applied to the wing leading edge had a large adverse effect on lift, drag, and pitching-moment characteristics. Roughness also reduced the maximum values of $C_{l\psi}$.

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INTRODUCTION

Highly swept-back wings are being employed as a means of minimizing compressibility effects at high subsonic and supersonic speeds. Large amounts of sweep have, however, presented problems in obtaining adequate maximum lift and satisfactory stability and control characteristics at low speeds. Low-scale tests (see, for example, references 1 and 2) have shown that unsatisfactory variations in the low-speed aerodynamic characteristics may be obtained, which result to a large extent from the spanwise flow of the air in the boundary layer. Because of the dependence of boundary-layer behavior on Reynolds number, the need for aerodynamic data at large values of Reynolds number is apparent. Accordingly, wind-tunnel tests have been made in the Langley 19-foot pressure tunnel of a particular swept-back wing to determine its low-speed characteristics up to reasonably high values of Reynolds number.

The wing had a sweepback angle of 42° , an aspect ratio of 4, and NACA 64₁-112 airfoil sections normal to the 0.273-chord line.

Aerodynamic characteristics in pitch were determined over a Reynolds number range from 1,700,000 to 9,500,000 and aerodynamic characteristics in yaw, from 1,700,000 to 5,300,000. Tests were made of the plain wing, the wing with partial-span split flaps, and the wing with a spoiler-type lateral-control device for conditions of leading edge smooth and leading edge rough.

COEFFICIENTS AND SYMBOLS

The data are referred to a system of stability axes shown in figure 1. Moments are referred to the quarter-chord point of the mean aerodynamic chord.

C_L lift coefficient $\left(\frac{\text{Lift}}{qS}\right)$

C_D drag coefficient $\left(\frac{D}{qS}\right)$

C_X longitudinal-force coefficient $\left(\frac{X}{qS}\right)$

C_Y lateral-force coefficient $\left(\frac{Y}{qS}\right)$

C_l	rolling-moment coefficient $\left(\frac{L}{qSb}\right)$
C_m	pitching-moment coefficient $\left(\frac{M}{qS\bar{c}}\right)$
C_n	yawing-moment coefficient $\left(\frac{N}{qSb}\right)$
R	Reynolds number $\left(\frac{\rho V \bar{c}}{\mu}\right)$
M_o	free-stream Mach number (V/a)
α	angle of attack measured in plane of symmetry, degrees
ψ	angle of yaw, degrees; positive when right wing is back
C_{l_ψ}	rate of change of rolling-moment coefficient with angle of yaw, per degree $\left(\frac{\partial C_l}{\partial \psi}\right)$
C_{n_ψ}	rate of change of yawing-moment coefficient with angle of yaw, per degree $\left(\frac{\partial C_n}{\partial \psi}\right)$
C_{Y_ψ}	rate of change of lateral-force coefficient with angle of yaw, per degree $\left(\frac{\partial C_Y}{\partial \psi}\right)$
$\frac{\partial C_{l_\psi}}{\partial C_L}$	rate of change of effective dihedral parameter with lift coefficient, per degree
Lift = -Z	
D	drag (-X at zero yaw)
X	longitudinal force
Y	lateral force
Z	vertical force
L	rolling moment
M	pitching moment

N	yawing moment
S	wing area
b	wing span
\bar{c}	mean aerodynamic chord $\left(\frac{2}{S} \int_0^{b/2} c^2 dy \right)$; measured parallel to plane of symmetry
\bar{x}	distance from leading edge of root chord to quarter chord of mean aerodynamic chord $\left(\frac{2}{S} \int_0^{b/2} cx dy \right)$; measured parallel to plane of symmetry
c	local chord; measured parallel to plane of symmetry
x	longitudinal distance from leading edge of root chord to quarter-chord point of each section; measured parallel to plane of symmetry
y	spanwise coordinate
q	free-stream dynamic pressure $\left(\frac{1}{2} \rho v^2 \right)$
V	free-stream velocity
ρ	mass density of air
μ	coefficient of viscosity
a	velocity of sound

MODEL

The plan form of the wing is shown in figure 2. The angle of sweep of the leading edge is 42° and the wing sections perpendicular to the 0.273-chord line are NACA 64₁-112 airfoil sections. The 0.273-chord line of each wing panel is the quarter-chord line of a straight panel which has been rotated 40° about the quarter-chord

point of its root chord. The airfoil sections parallel to the plane of symmetry have a maximum thickness of 9.6 percent chord located at approximately 38 percent chord. The aspect ratio is 4.01 and the taper ratio is 0.625. The tips are rounded off beginning at $0.975\frac{b}{2}$ in both plan form and cross section. The wing has no geometric dihedral or twist.

The span of the split flaps is 50 percent of the wing span. (See fig. 2.) The flap chord is 18.4 percent of the wing chord and the flap deflection with respect to the hinge line is 60° measured between the wing lower surface and the flap.

The installation of the spoiler is shown in figure 3. The height of the spoiler, 0.052 chord, is equal to the wing thickness at the chordwise station where the spoiler is located.

The wing was constructed of laminated mahogany and the flaps and the spoiler were of sheet metal. The wing was lacquered and sanded to obtain a smooth surface. A leading-edge roughness was obtained by application of No. 60 (0.011-inch mesh) carborundum grains to a thin layer of shellac over a surface length of 8 percent chord measured from the leading edge on both upper and lower surfaces. The grains covered 5 to 10 percent of the affected area.

APPARATUS AND TESTS

The tests were made in the Langley 19-foot pressure tunnel. The mounting of the wing for the pitch tests is shown in figure 4 and for the yaw tests in figure 5. For the yaw tests the end of the support strut was shielded by a fairing formed by a part of a sphere to which was attached an afterbody. The fairing was 20 inches long, 14 inches wide, and extended 4 inches below the wing surface.

The pitch characteristics of the smooth and rough wings with and without split flaps were determined at zero yaw through an angle-of-attack range at the following Reynolds numbers and Mach numbers:

R	M ₀	Tunnel pressure (absolute) (lb/sq in.)
1,720,000	0.100	14.7
3,000,000	.070	33
4,350,000	.098	33
5,300,000	.120	33
6,800,000	.154	33
8,100,000	.186	33
9,500,000	.220	33

Six-component data were obtained for the wing with spoiler at a Reynolds number of 5,300,000. Stall characteristics were studied at Reynolds numbers of 1,700,000 and 6,800,000 by means of tufts attached to the upper surface of the wing beginning at 20 percent chord for the wing smooth and 10 percent chord for the wing rough; however, only data at a Reynolds number of 6,800,000 are presented herein.

The aerodynamic characteristics of the wing with the leading edge both smooth and rough were obtained through an angle-of-yaw range of -10° to 25° at several angles of attack for a Reynolds number of 5,300,000. The lateral-stability parameters of the smooth wing with and without flaps were determined from tests made through an angle-of-attack range for yaw angles of $\pm 5^{\circ}$ at several values of Reynolds number between 1,700,000 and 5,300,000. Similar tests were made with the leading edge rough at a Reynolds number of 5,300,000.

CORRECTIONS TO DATA

The effects of the two-support system (fig. 4) on lift, drag, and pitching moment were determined by tare tests and the data at zero yaw have been corrected for these effects. No tare tests were made to determine the effects of the single support (fig. 5), but approximate corrections to the lift, drag, and pitching moment in yaw have been applied. The data have also been corrected for air-stream misalignment.

The jet-boundary corrections to the angle of attack and drag coefficient, which were calculated at zero yaw from reference 3, are as follows:

$$\Delta\alpha = 0.99C_L$$

$$\Delta C_D = 0.0149C_L^2$$

The correction to the pitching-moment coefficient due to the tunnel-induced distortion of the loading is

$$\Delta C_m = 0.004C_L$$

The correction to the rolling-moment coefficient due to the spoiler, as determined from reference 4 for an unswept wing, is

$$\Delta C_l = -0.018C_l$$

All these corrections were added to the uncorrected data.

No corrections have been applied to the side force, yawing moment, and rolling moment except for the rolling moment due to the spoiler.

No correction has been applied for wake blockage (reference 5). This correction which is dependent on the profile drag is negligible for most of the data presented. For conditions of leading edge rough or leading edge smooth at the lowest Reynolds number, correcting for wake blockage would reduce the absolute values of the coefficients by approximately 2 percent at high angles of attack.

RESULTS AND DISCUSSION

Aerodynamic Characteristics in Pitch

The lift characteristics and the rolling-moment characteristics near maximum lift are presented in figure 6. At some of the high Reynolds numbers no test data were obtained beyond the stall because

of excessive model vibration. The maximum lift coefficients as a function of Reynolds number are plotted in figure 7. Results of tuft surveys at a Reynolds number of 6,800,000 are given in figures 8 and 9. The pitching-moment coefficients are presented in figure 10 as a function of lift coefficient and also, at high angles of attack, as a function of angle of attack. Drag coefficients are given in figure 11 and some information on the influence of the drag variations on glide characteristics is given in figure 12. The aerodynamic characteristics of the wing with spoiler are shown in figures 13 to 15.

Lift and stalling characteristics.- For the smooth wing, the lift-curve peaks (fig. 6) are smooth and well rounded at the lowest Reynolds number (1,760,000) but become sharper as the Reynolds number is increased. Up to a Reynolds number of 6,800,000 the value of $C_{L_{max}}$ increased with increasing Reynolds number. (See fig. 7.) The value of $C_{L_{max}}$ decreased slightly with further increase in Reynolds number. The maximum values of $C_{L_{max}}$ obtained were 1.12 at $\alpha = 19^\circ$ with flaps off and 1.33 at $\alpha = 17^\circ$ with flaps on.

For the rough wing, the lift-curve peaks are well rounded and Reynolds number has little effect on lift. The maximum lift coefficients of approximately 0.98 with flaps off and 1.02 with flaps on show the low effectiveness at $C_{L_{max}}$ of the flap on the rough wing. At Reynolds numbers greater than 4,350,000 the maximum lift coefficient of the rough wing with flaps on was even lower than the maximum lift coefficient of the smooth wing with flaps off.

The tuft surveys show that quite different stall progressions were obtained depending on the Reynolds number or surface condition of the wing leading edge. Stall studies for the smooth wing at $R = 6,800,000$ (fig. 8) show outflow along the rear part of the wing beginning at moderate lift coefficients. Beyond $C_{L_{max}}$ the wing stalls rather abruptly over the outer half of the wing. This type of stall may be dangerous in landing. Stalling was not always symmetrical, as can be seen by the stall studies in figure 8 and the rolling-moment data in figure 6. The asymmetrical stall results from asymmetries in the wing and/or tunnel air flow.

The stall progressions for the smooth wing at the lowest Reynolds number (1,700,000) and the progression for the rough wing at any Reynolds numbers were very similar. This similarity is also

borne out by the force data. For the rough wing (fig. 9) and for the smooth wing at $R = 1,700,000$ (data not presented) appreciable outflow was first obtained near the leading edge over the outer part of the wing. As the angle of attack was increased the general direction of the tufts on all parts of the wing moved in a clockwise direction on the left wing and counterclockwise on the right wing. Any region where the direction of the tufts was forward of the perpendicular to the wing center line was interpreted as a stalled region. Stalling began near the leading edge ($0.10c$ to $0.20c$) from 50 to 75 percent of the semispan. Stalling progressed gradually rearward and fanned out until, at maximum lift, only the center third of the wing was unstalled. No large changes in rolling moment occurred for the rough wing.

On the basis of the tuft surveys the stalling characteristics of both the smooth and the rough wings are considered undesirable because of tip stalling.

Pitching-moment characteristics.- At $R = 1,700,000$ and at a moderate value of lift coefficient, there is a decided increase in stability as determined from the variation of pitching-moment coefficient with lift coefficient (fig. 10). Then at angles of attack several degrees below that for maximum lift unstable changes in pitching-moment coefficient occur, which result in a pitching-moment curve of a decided reflexed shape. The unstable variation of the pitching-moment coefficient apparently results from separation which occurred prematurely on the outer part of the wing. When the Reynolds number is increased to $4,350,000$ and to higher values, the pitching-moment curves are more nearly linear up to the maximum lift and, for these conditions, unstable changes in pitching moment resulting from tip stalling occur after the maximum lift coefficient has been attained. For Reynolds numbers of $6,800,000$ to $9,500,000$, initial test results for the wing with no flaps, although limited, indicate only small variations in pitching-moment coefficient at high angles of attack; hence the wing for these conditions might be considered to have marginal stability. Check tests, in which the wing surface was observed to have deteriorated slightly, show that the wing is definitely unstable at the stall. For design considerations, it is more practical to consider the results of the check tests as representative.

The wing with leading-edge roughness exhibits in general the same type of pitching-moment characteristics at all Reynolds numbers as were obtained with the smooth wing at $R = 1,700,000$.

Drag characteristics.- At a Reynolds number of 1,700,000, the drag coefficient of the smooth wing increases rapidly with lift coefficient, beginning at moderate values of lift coefficient. (See fig. 11.) This effect may be attributed to premature stalling. At moderate to high values of Reynolds number, no large increase in drag coefficient occurs until after $C_{L_{max}}$ is reached. For the rough wing the large drag rise occurs prematurely over the whole range of Reynolds number, which results in extremely high values of drag coefficient in the vicinity of maximum lift.

Flight tests reported in reference 6 show that when the vertical velocity in approach exceeds about 25 feet per second the piloting technique required for landing becomes extremely difficult. Based upon the data in figure 11 and a wing loading of 40 pounds per square foot, the smooth wing with split flaps at moderate to high values of Reynolds number is calculated to have a vertical velocity of 23 feet per second for lift coefficients from $0.85C_{L_{max}}$ to $C_{L_{max}}$. For the rough wing with flaps, the vertical velocity varies from 30 to 50 feet per second between $0.85C_{L_{max}}$ and $C_{L_{max}}$. These variations are more clearly shown in figure 12.

Spoiler characteristics.- The spoiler produced a maximum value of C_l of about 0.013 with flaps on at moderate angles of attack. This value is considered low. The data for the smooth wings (figs. 13 and 14) indicate that the spoiler effectiveness decreases as maximum lift is approached and that the loss in effectiveness is smaller when the flaps are on. Data for the rough wing with flaps off (fig. 15) show that the spoiler is ineffective at lift coefficients above 0.7. Data for the wing with flaps on (not presented) show that the spoiler is ineffective at lift coefficients greater than 0.95.

Aerodynamic Characteristics in Yaw

The lateral-stability parameters C_{l_y} and C_{n_y} of the smooth wing are plotted in figure 16 as a function of the lift coefficient for several values of Reynolds number. Similar data for the rough wing are given in figure 17 for a Reynolds number of 5,300,000. The lateral-stability parameters were obtained from the tests made at 0° and $\pm 5^\circ$ yaw. Aerodynamic characteristics through a range of yaw angle at several angles of attack are presented in figures 18 and 19.

Rolling-moment characteristics:- The variation of the effective dihedral parameter $C_{l\psi}$ with lift coefficient was greatly influenced by Reynolds number, particularly when the Reynolds number was increased from 1,720,000 to 3,000,000. (See fig. 16.) When the Reynolds number was increased the linear part of the curve of $C_{l\psi}$ extended over a greater lift-coefficient range and the maximum values of $C_{l\psi}$ were increased. For the wing with flaps on, the slope of the curve of $C_{l\psi}$ was increased also. The large scale effect shown may be due to the particular airfoil section employed; hence, this result should not be considered applicable to all wings.

At a Reynolds number of 1,720,000 and with flaps off (fig. 16(a)), $C_{l\psi}$ increased linearly with C_L in the low lift-coefficient range and reached a maximum value of 0.0020 at $C_L = 0.5$ to 0.7. The value of $C_{l\psi}$ then decreased and finally reversed in sign; that is, a negative dihedral effect was obtained. With flaps on and at the same Reynolds number (fig. 16(b)), $C_{l\psi}$ increased with lift coefficient to a maximum value of 0.0034 at $C_L = 1.05$ and then decreased rapidly. For $R = 5,300,000$, the curves were linear over most of the lift range and the maximum values of $C_{l\psi}$ obtained were about 0.0040 at $C_L = 0.9$ with flaps off and 0.0050 at $C_L = 1.25$ with flaps on. The change in $C_{l\psi}$ per unit change in C_L is approximately 0.0044 in the linear range of the curves for all conditions except for the condition of flaps on and $R = 1,720,000$, for which the change is 0.0026. For this wing, the almost blunt wing tips may contribute as much as 15 percent to the value of $\partial C_{l\psi} / \partial C_L$. (See reference 7.)

The variations of $C_{l\psi}$ with lift coefficient for the rough wing at a Reynolds number of 5,300,000 (fig. 17) are similar to those for the smooth wing at a Reynolds number of 1,720,000. The maximum values for the rough wing are approximately 60 percent of those for the smooth wing at a Reynolds number of 5,300,000. The maximum values were obtained near the lift coefficient at which stalling first began (fig. 9). Little scale effect on $C_{l\psi}$ is

expected for the rough condition inasmuch as there was only a small scale effect on the aerodynamic characteristics of the rough wing in pitch.

As an aid in interpreting the values of $C_{l_{\psi}}$ in terms of effective dihedral, it may be noted that a unit change in geometric dihedral angle on a 40° swept-back wing caused a change in $C_{l_{\psi}}$ varying from 0.00018 at $C_L = 0.2$ to 0.00012 at $C_L = 1.0$ (reference 8).

The slope of the curve of rolling-moment coefficient against angle of yaw (fig. 18) decreased at angles of yaw above 10° for the smooth wing at high angles of attack. For the rough wing, the curve of $C_{l_{\psi}}$ for the flaps-off, high angle-of-attack condition (fig. 19) has a negative slope (negative effective dihedral) at small angles of yaw but has a large positive slope at angles of yaw above 10° .

Yawing-moment characteristics.— The values of $C_{n_{\psi}}$ for the smooth wing at the higher Reynolds numbers increased negatively with lift coefficient, which indicates increasing directional stability. Maximum values of $C_{n_{\psi}}$ were about -0.0008 at $C_L = 1.0$ with flaps off and -0.0013 at $C_L = 1.25$ with flaps on. For the smooth wing at $R = 1,720,000$ and for the rough wing at $R = 5,300,000$, irregular variations in $C_{n_{\psi}}$ are shown in figures 16 and 17 at moderate to high lift coefficients.

As shown in figure 18 the yawing-moment curves of the smooth wing at high angles of attack show reversals at angles of yaw above 10° and 15° .

CONCLUSIONS

An investigation was made of a 42° swept-back wing of aspect ratio 4, taper ratio 0.625, and NACA 64₁-112 airfoil sections to determine its low-speed aerodynamic characteristics in pitch and in yaw at high Reynolds numbers. The following conclusions were indicated:

1. The wing characteristics at high angles of attack were greatly influenced by Reynolds number in the range from 1,700,000 to 5,300,000 but were little affected in the range from 5,300,000 to 9,500,000. The principal effect of increasing the value of Reynolds number was to delay wing stalling to higher angles of attack.

2. The maximum lift coefficients in the higher range of Reynolds number were about 1.1 without flaps and about 1.3 with half-span split flaps deflected 60° . Abrupt tip stalling caused unstable changes in the pitching moment at maximum lift.

3. The effective dihedral parameter $C_{l\psi}$ varied approximately linearly with lift coefficient at a Reynolds number of 5,300,000 and reached a maximum value near maximum lift of about 0.0040 without flaps and 0.0050 with flaps.

4. At Reynolds numbers above 1,700,000, roughness in the form of carborundum grains applied to the wing leading edge had a large adverse effect on lift, drag, and pitching-moment characteristics. Roughness also reduced the maximum values of $C_{l\psi}$.

5. The maximum static rolling moment produced by a 0.475 semispan spoiler at 72 percent chord was only 0.013.

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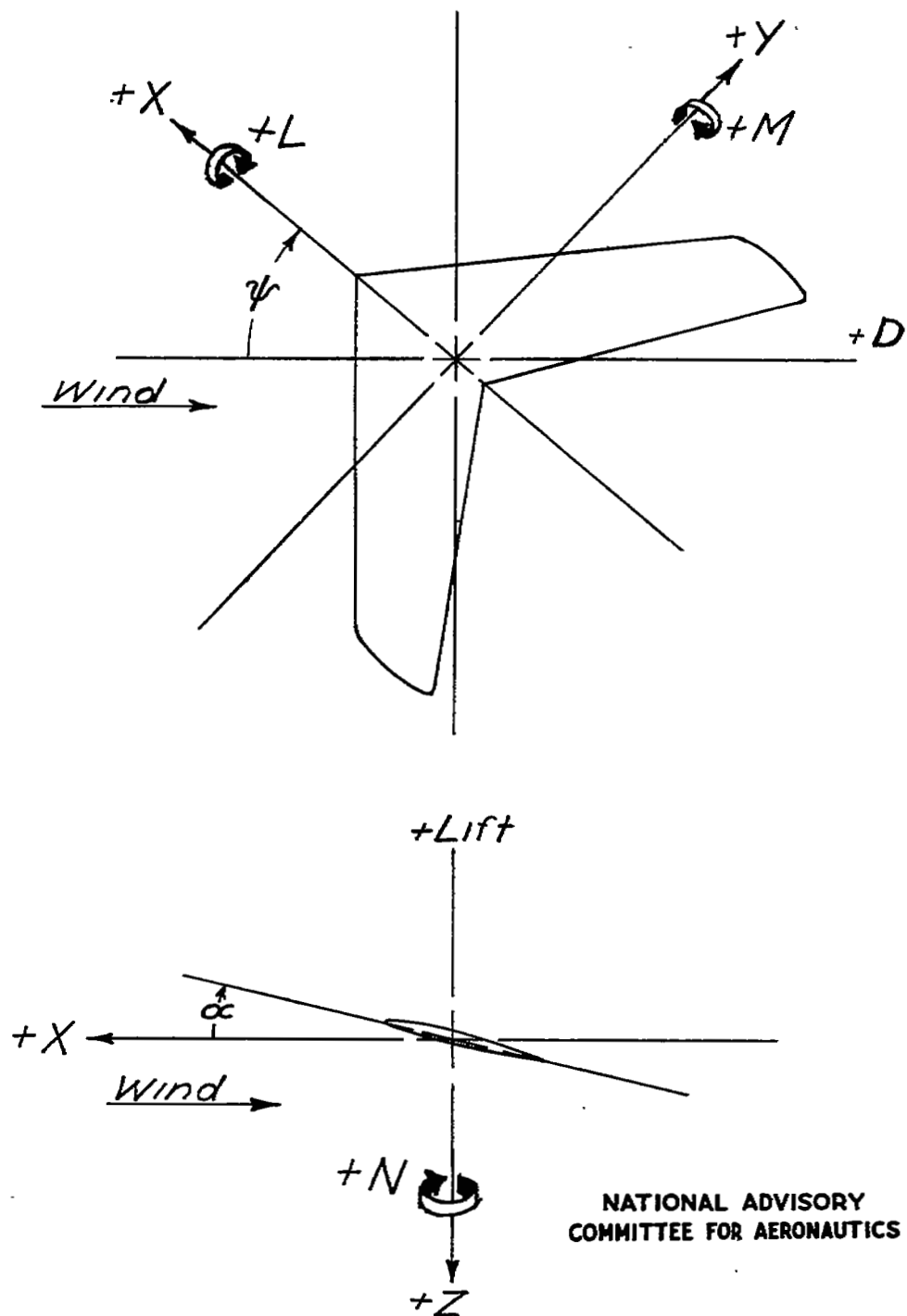


Figure 1.- System of axes used.

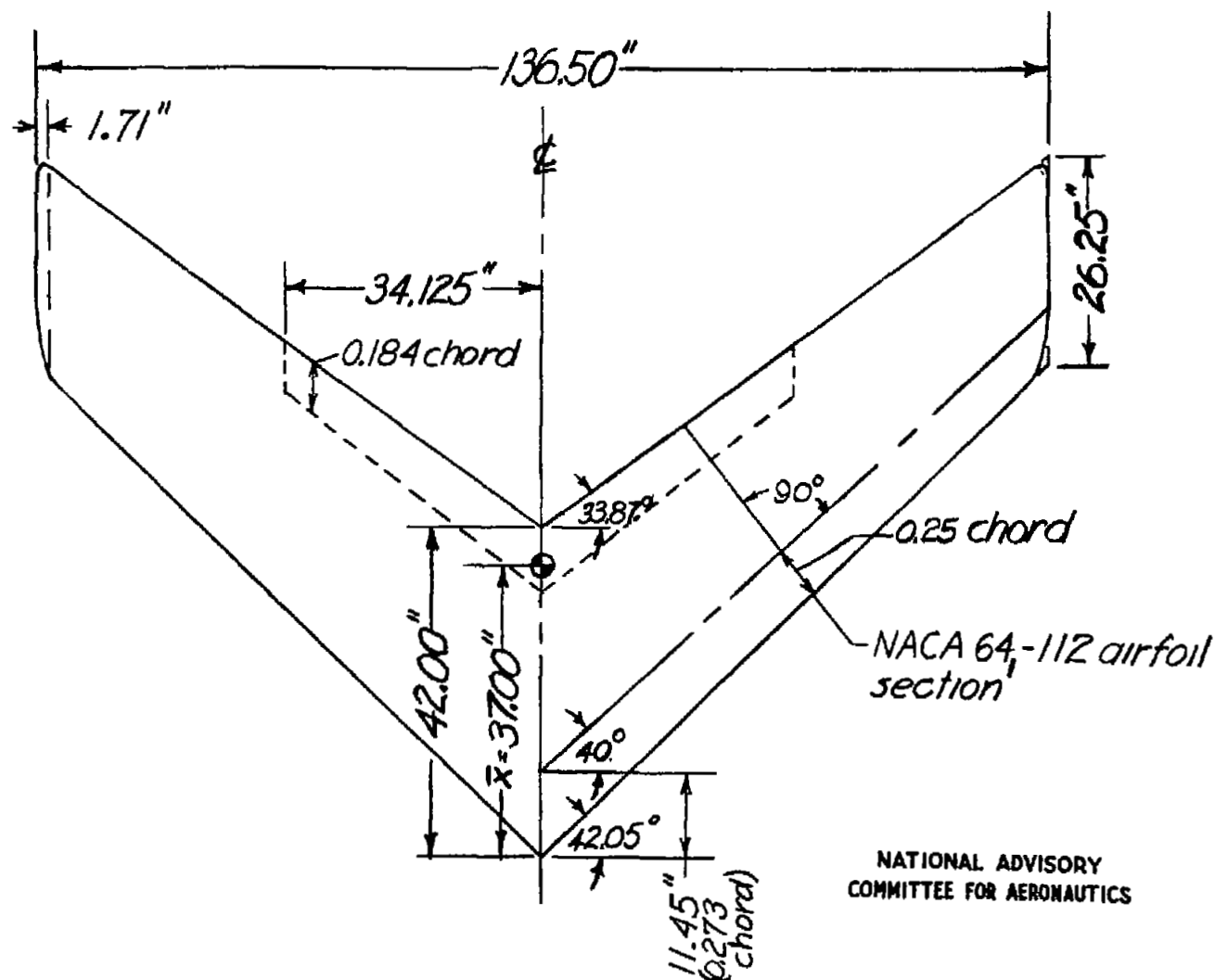


Figure 2.- Plan form of wing. Aspect ratio, 4.01; area, 4643 square inches; mean aerodynamic chord, 34.71 inches.

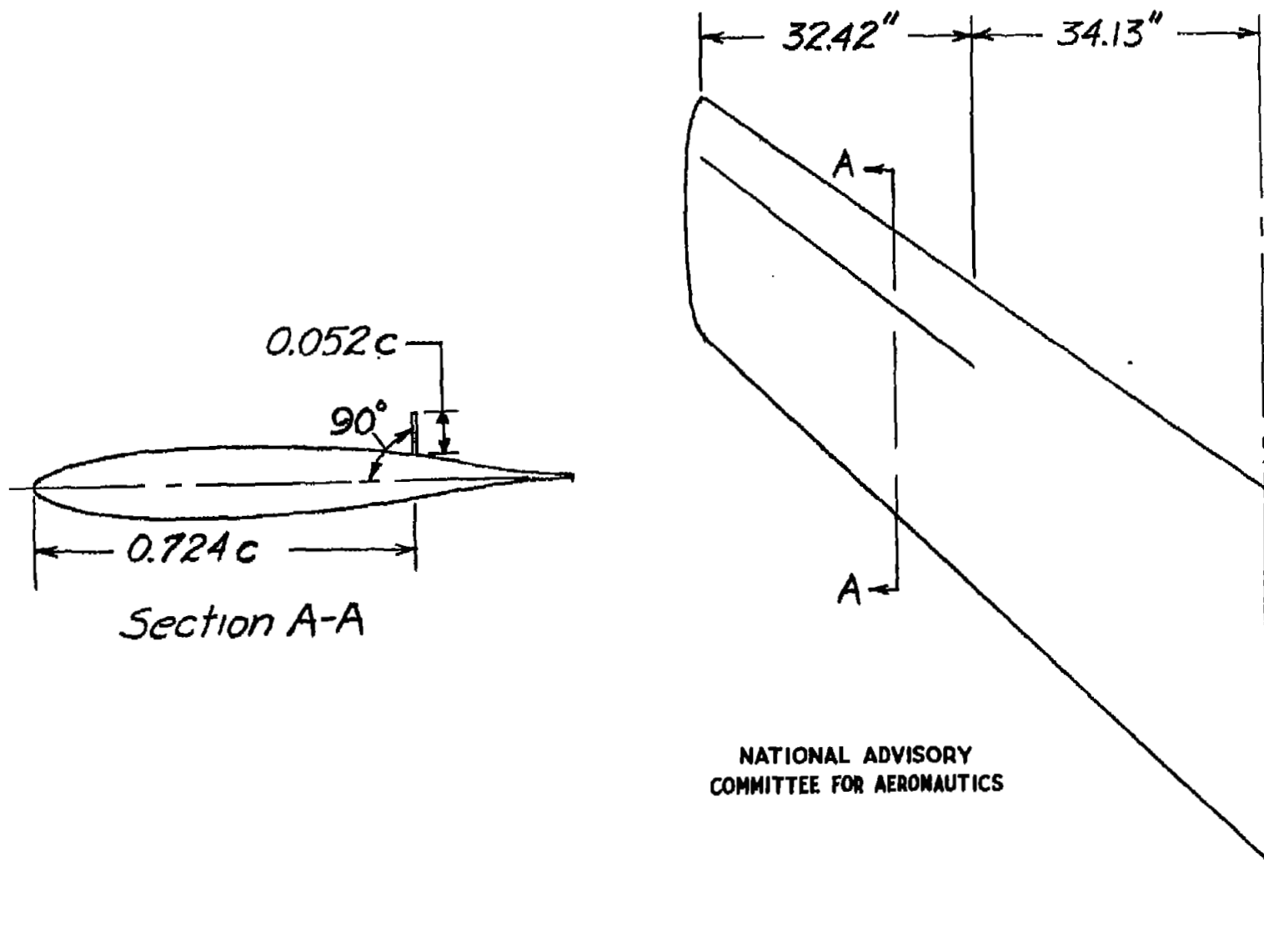
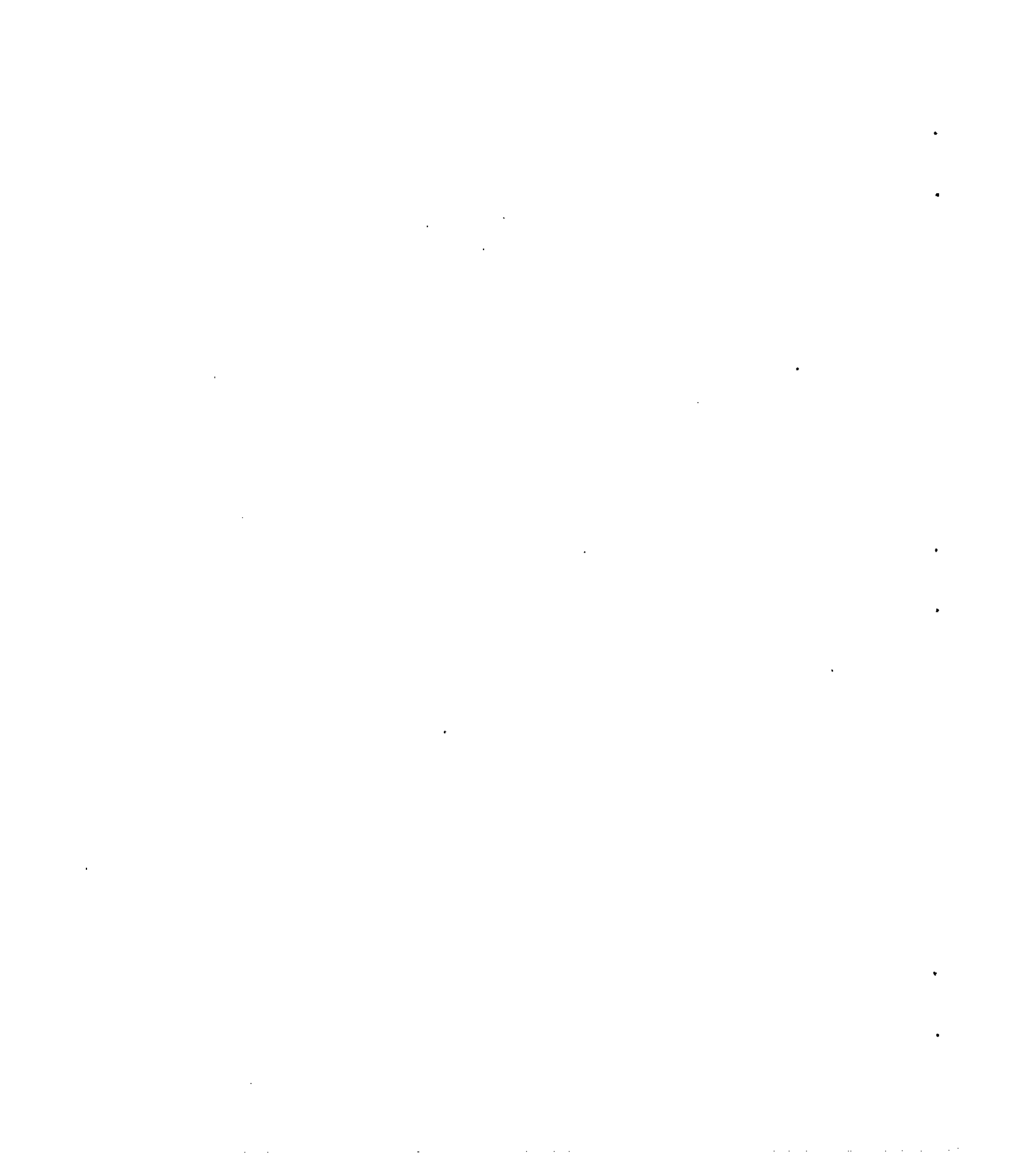


Figure 3.- Spoiler installation.



Figure 4.- Wing mounted for pitch tests in the Langley 19-foot pressure tunnel.



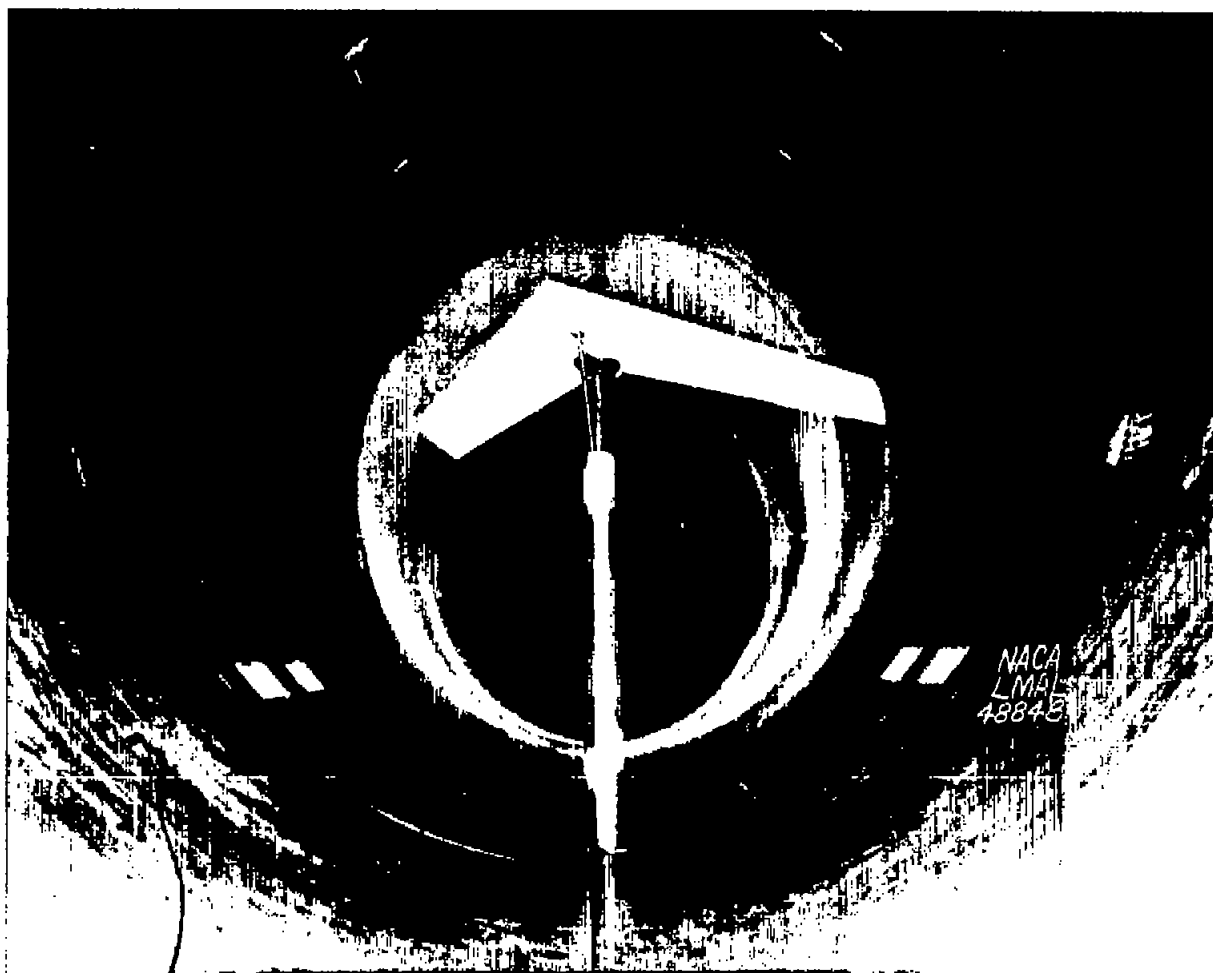


Figure 5.- Wing mounted for yaw tests in the Langley 19-foot pressure tunnel.

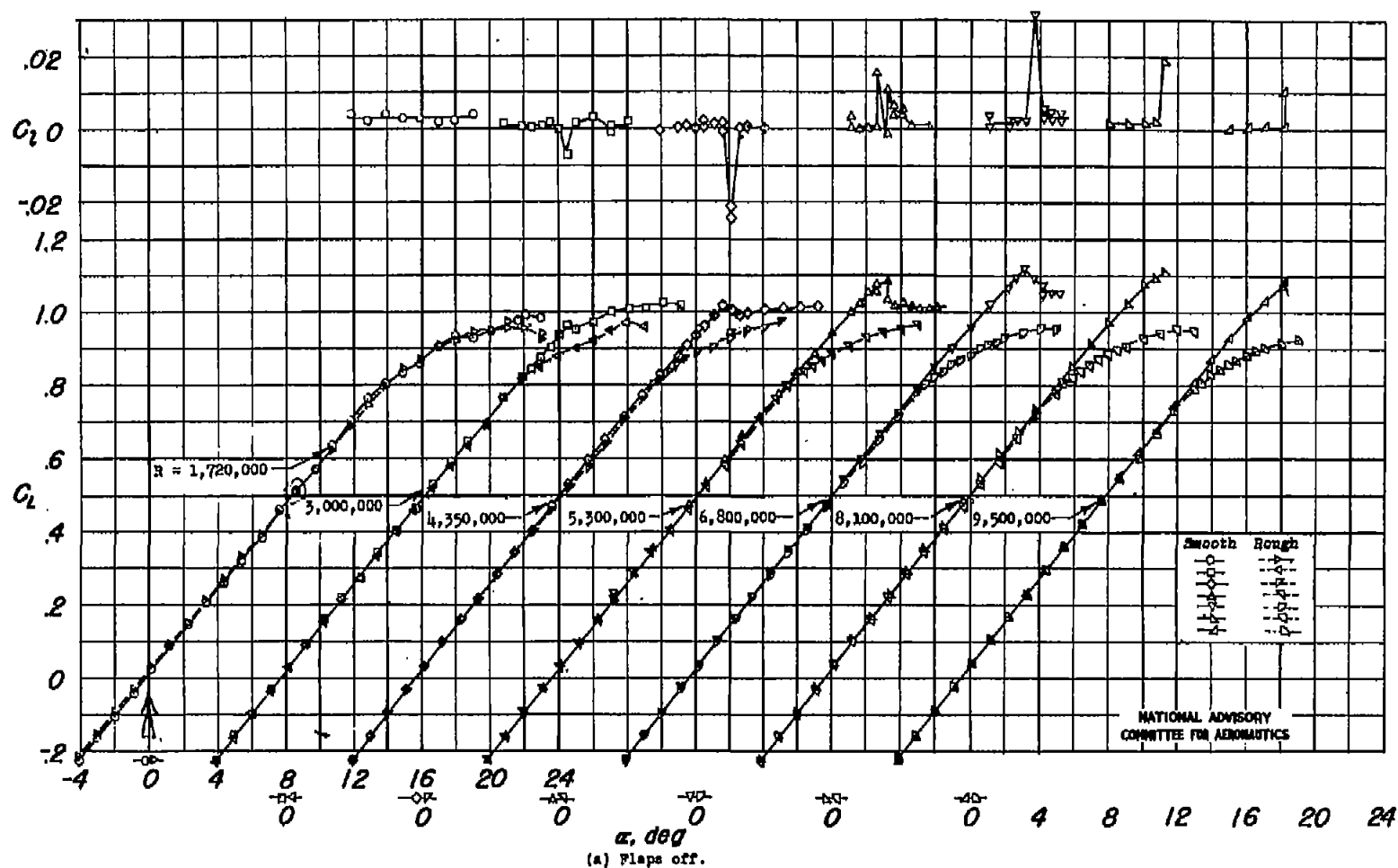


Figure 6.- Lift characteristics for various values of Reynolds number, 42° swept-back wing with and without roughness; $\gamma = 0^\circ$.

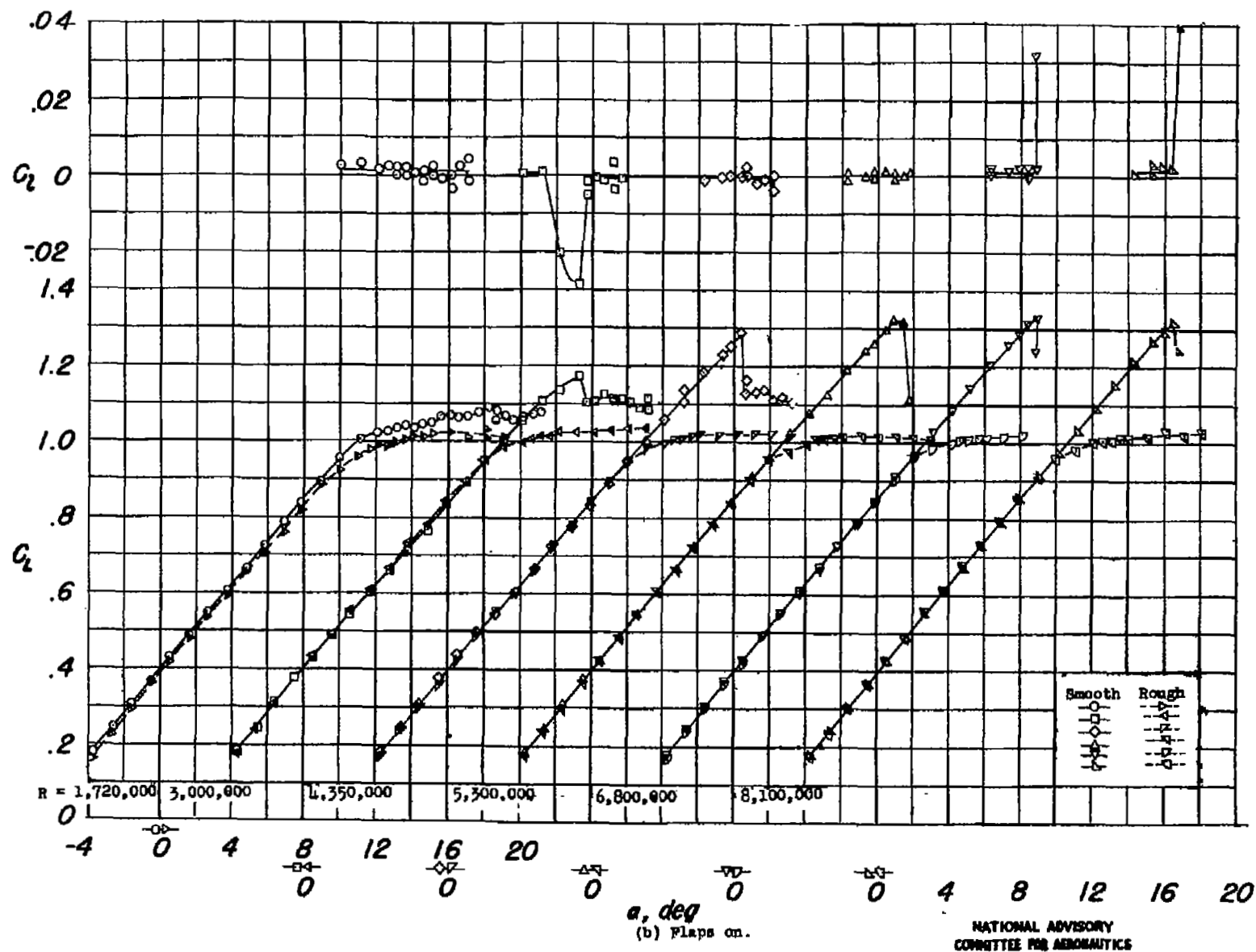


Figure 6.- Concluded.

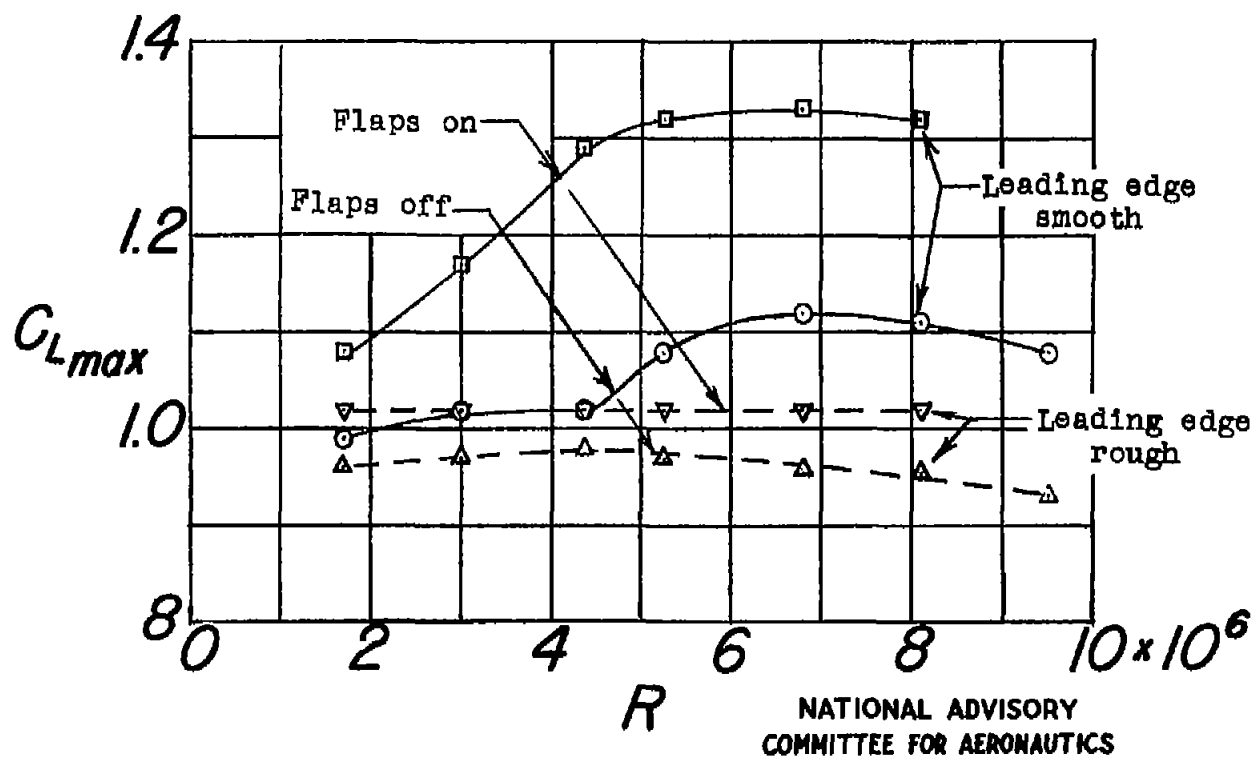


Figure 7.- Variation of maximum lift coefficient with Reynolds number.

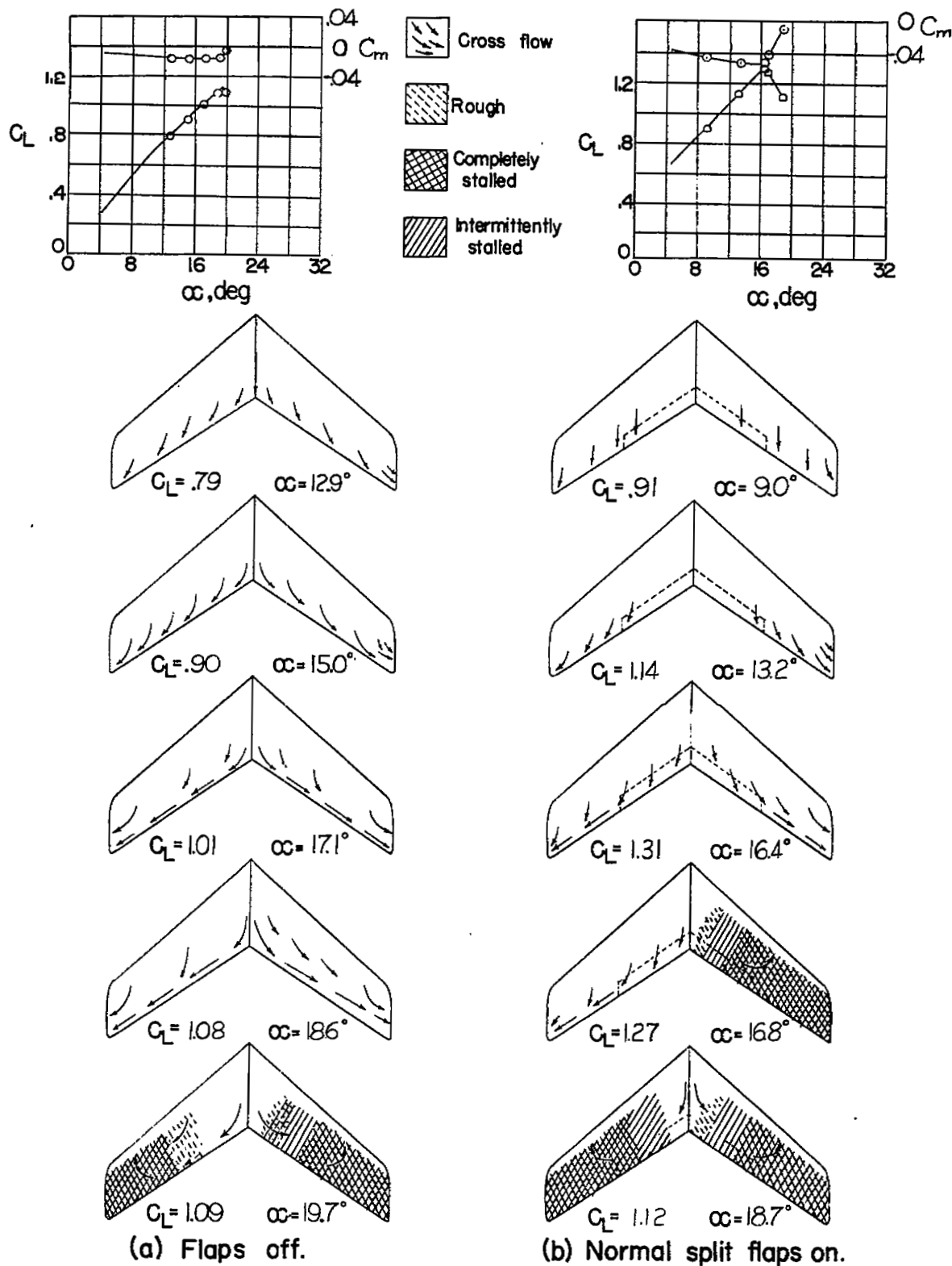


Figure 8.-Stalling characteristics of 42° swept-back wing with leading edge smooth. $R = 6,800,000$.

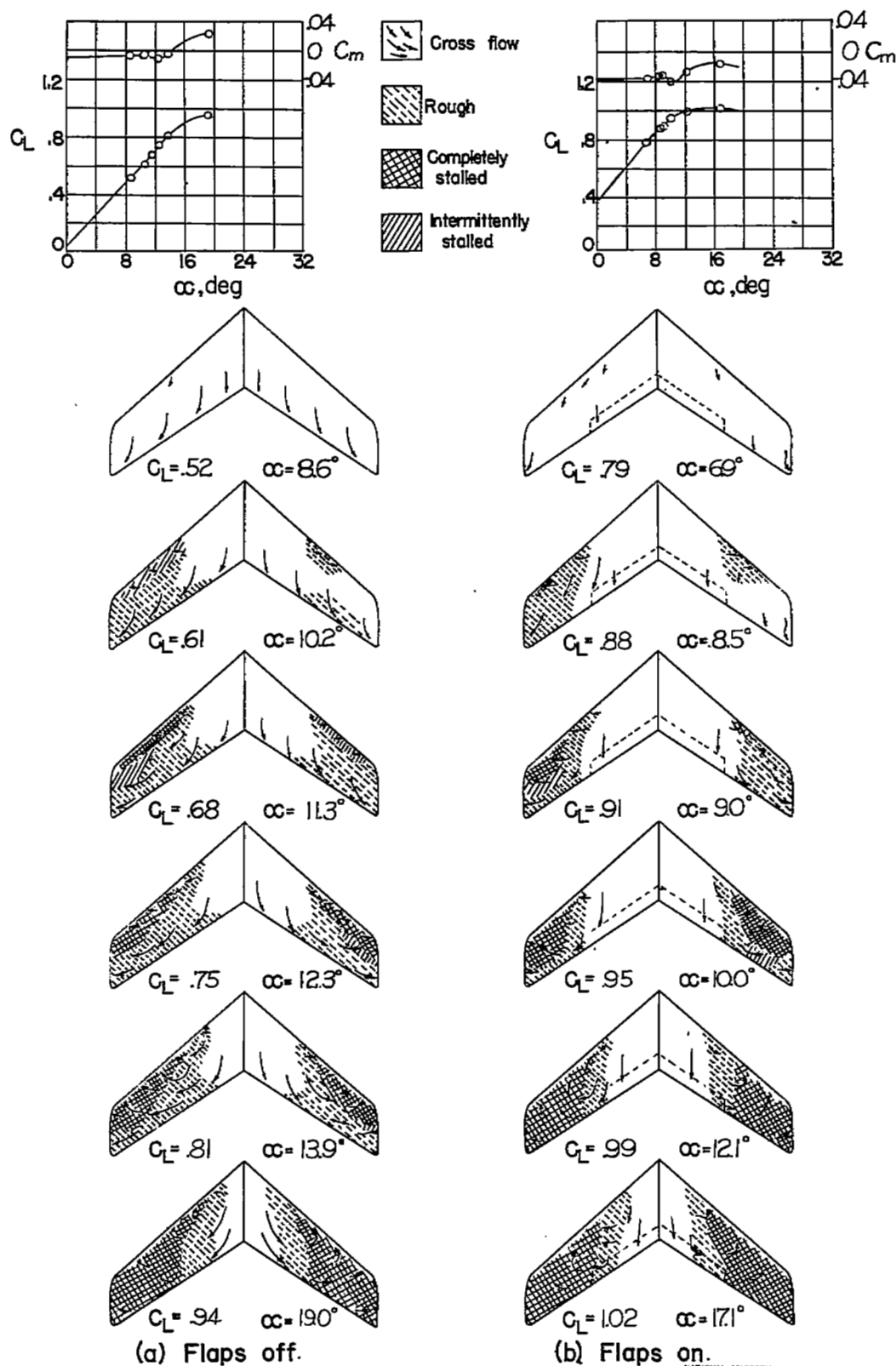
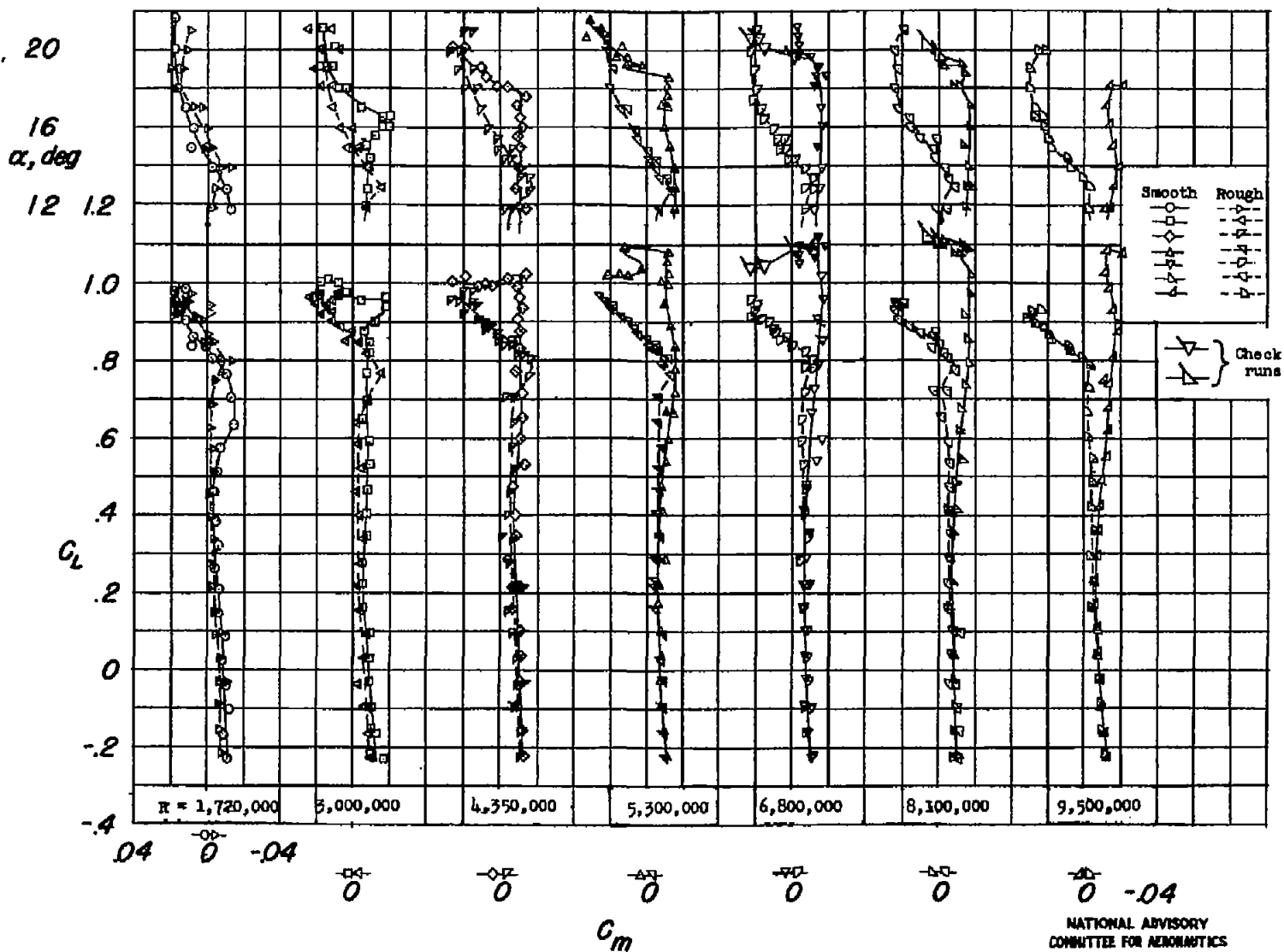


Figure 9.— Stalling characteristics of 42° swept-back wing with leading edge roughness. $R=6,800,000$.



(a) Flaps off.

Figure 10.- Pitching-moment characteristics for various values of Reynolds number. 42° swept-back wing with and without leading-edge roughness; $\tau = 0^\circ$

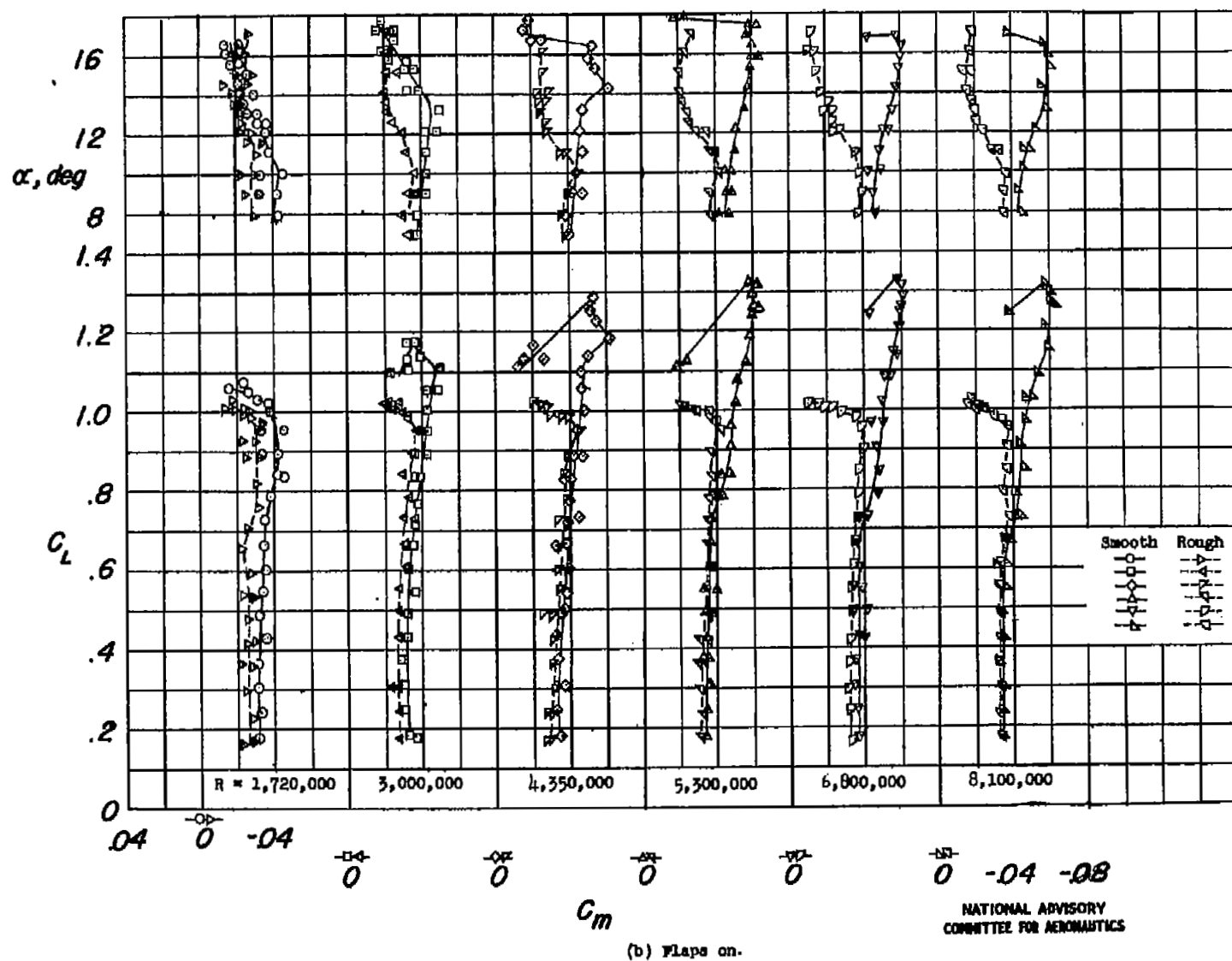
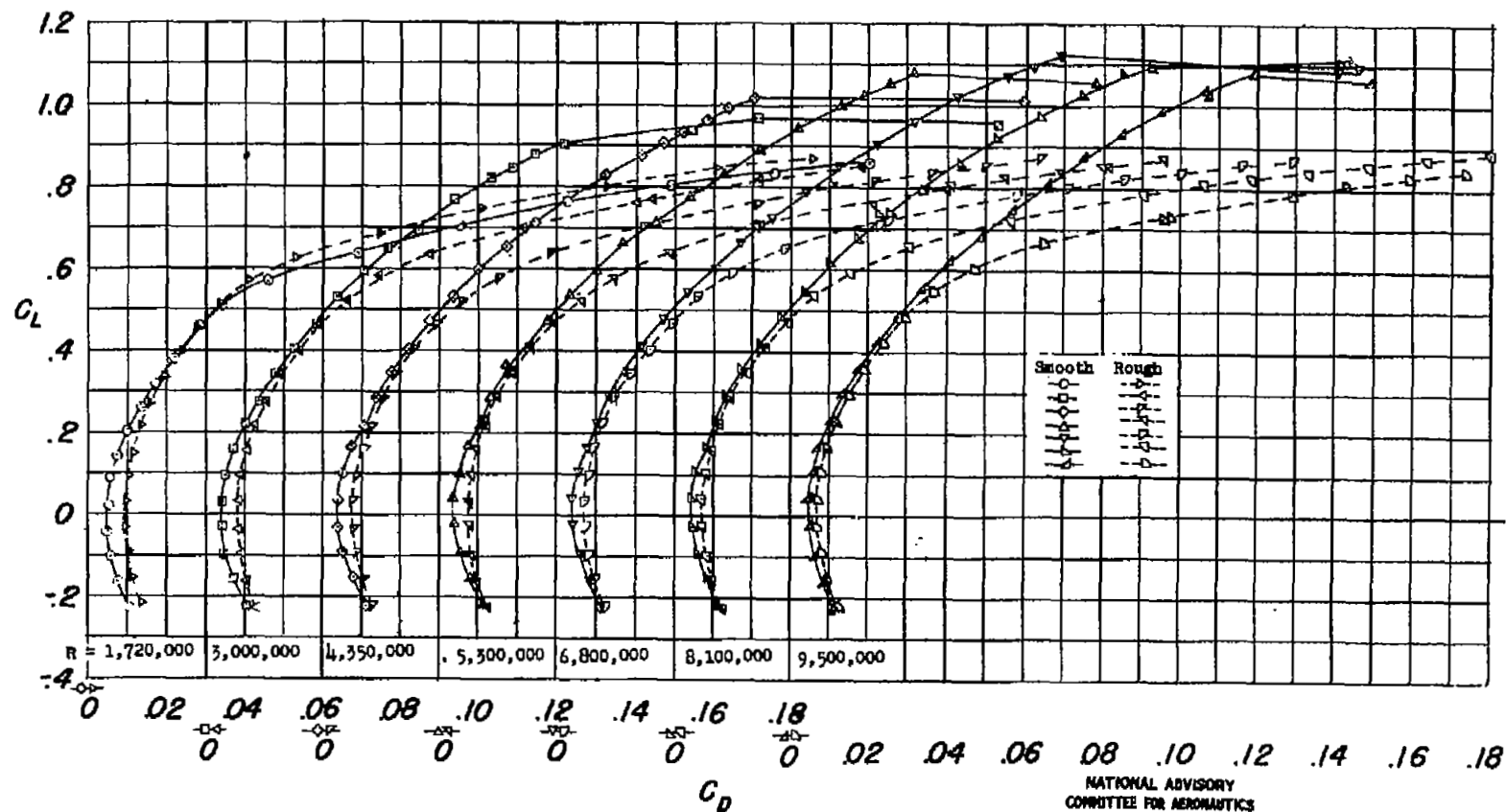


Figure 10.- Concluded.



(a) Flaps off.

Figure 11.- Drag characteristics for various values of Reynolds number, 42° swept-back wing with and without leading-edge roughness. $\alpha = 0^\circ$.

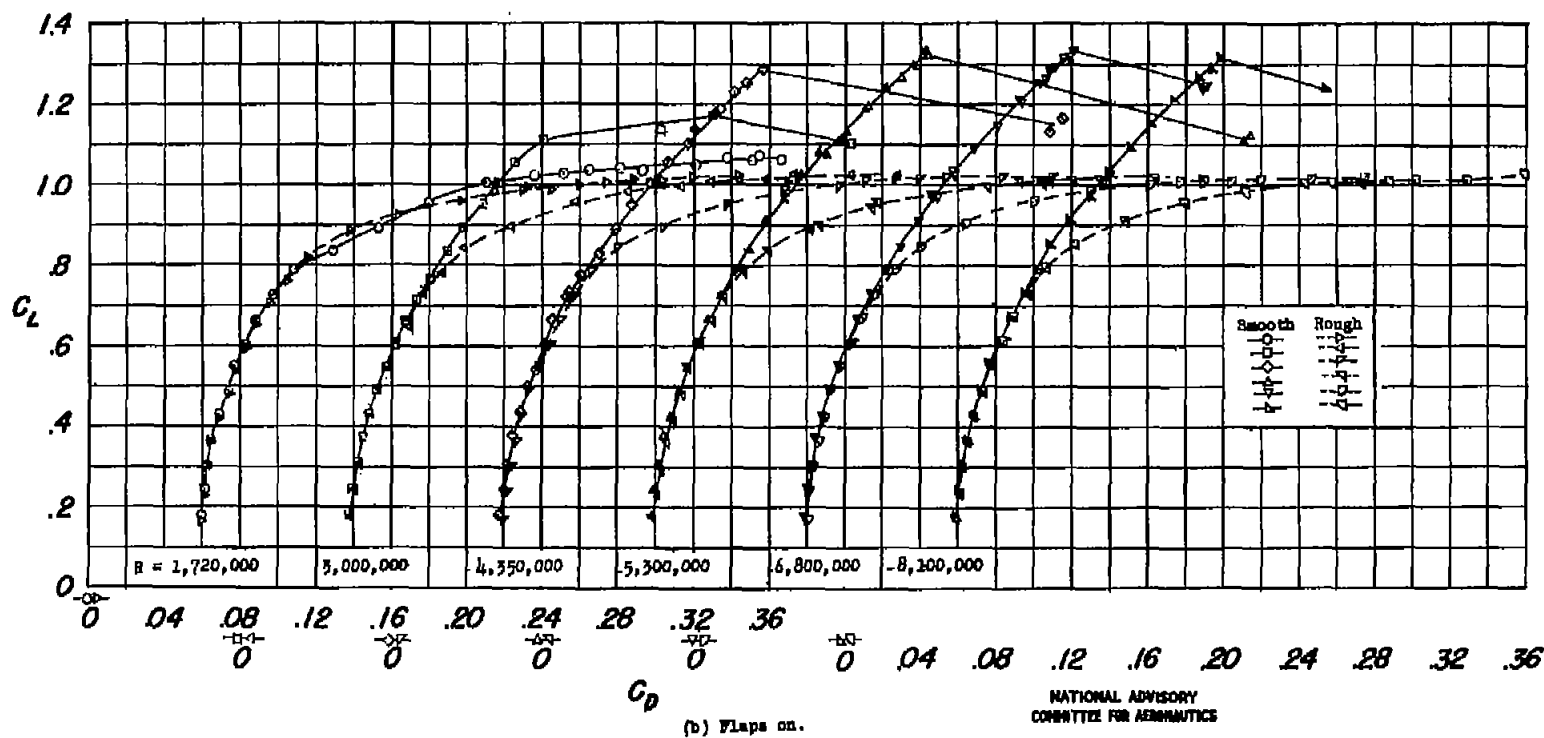


Figure 11.- Concluded.

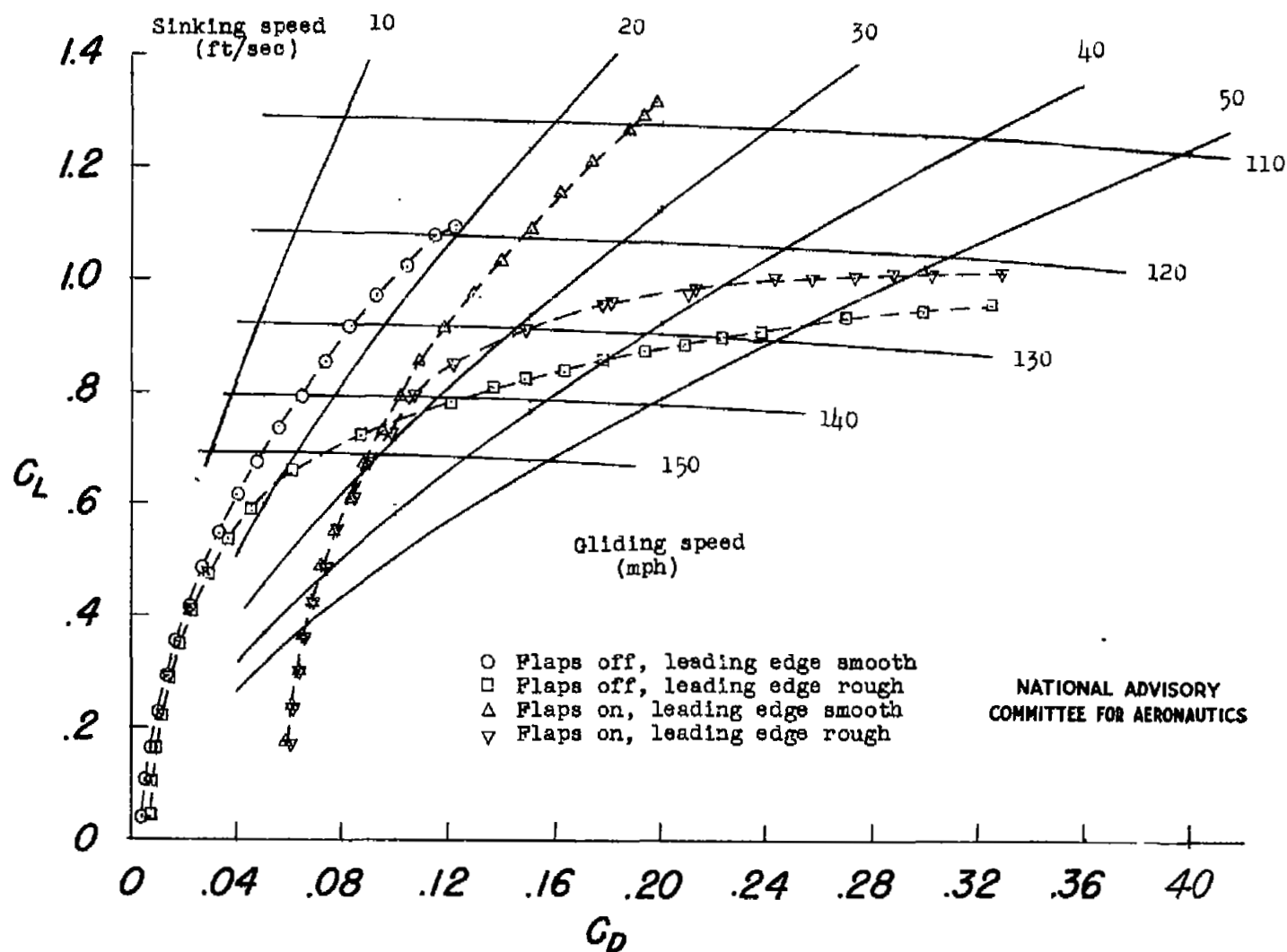


Figure 12.- Glide characteristics of 42° swept-back wing for wing loading of 40 pounds per square foot. Experimental data for $R = 8,100,000$.

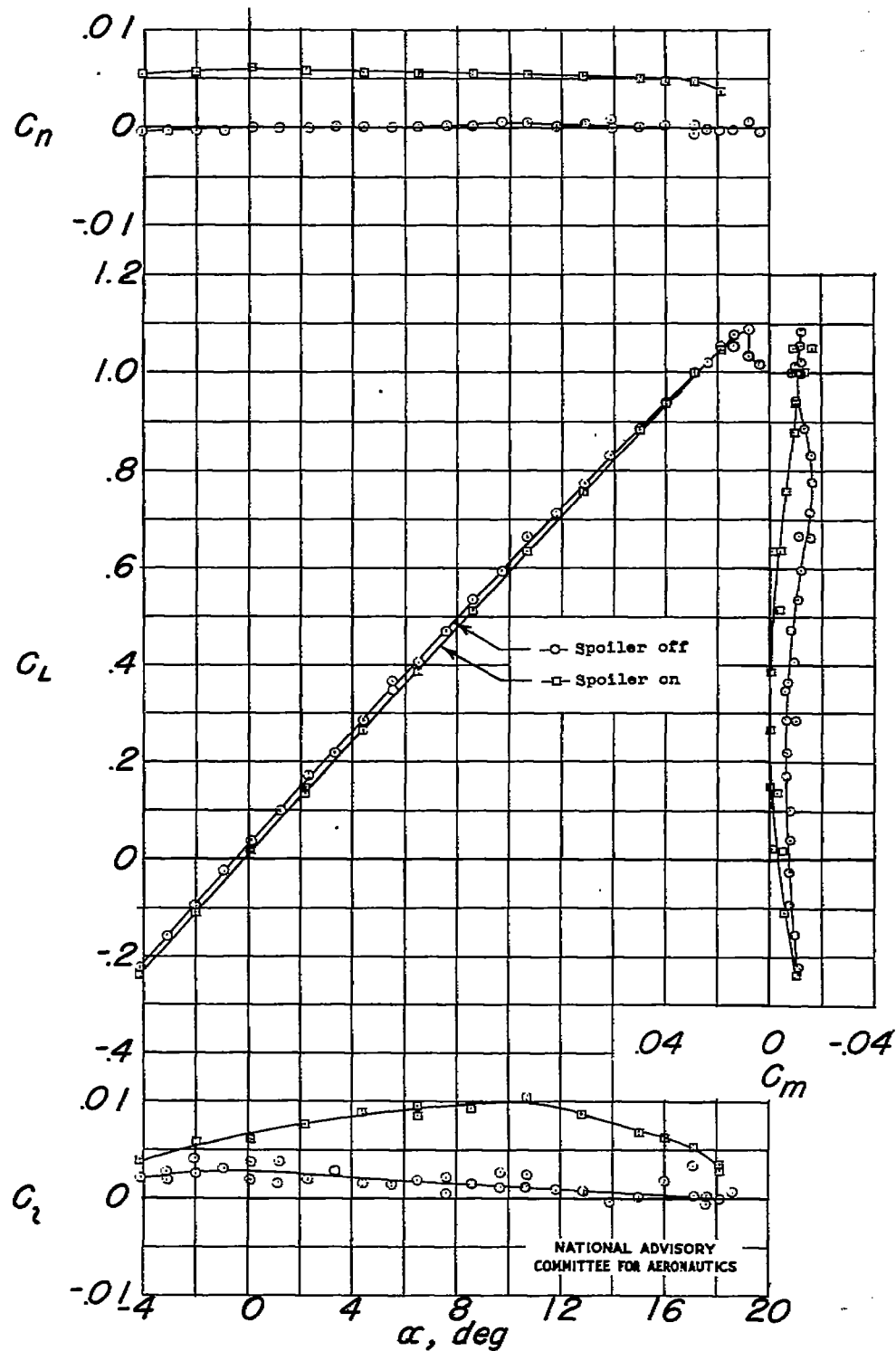


Figure 13.- Aerodynamic characteristics of 42° swept-back wing with spoiler. Leading edge smooth; $R = 5,300,000$; $\gamma = 0^\circ$.

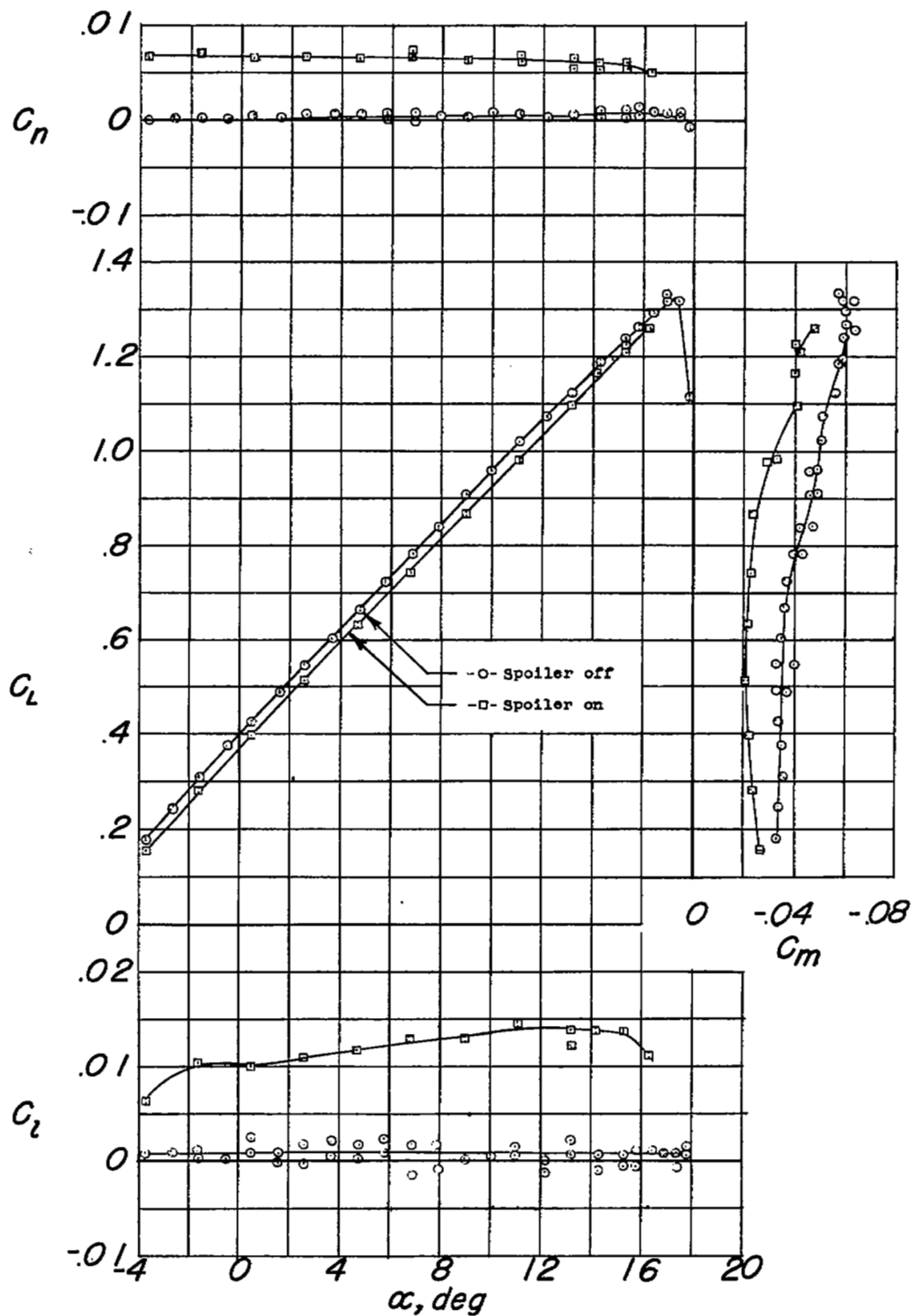


Figure 14.- Aerodynamic characteristics of 42° swept-back wing with spoiler. Leading edge smooth; flaps on; $R = 5,500,000$; $\beta = 0^\circ$.

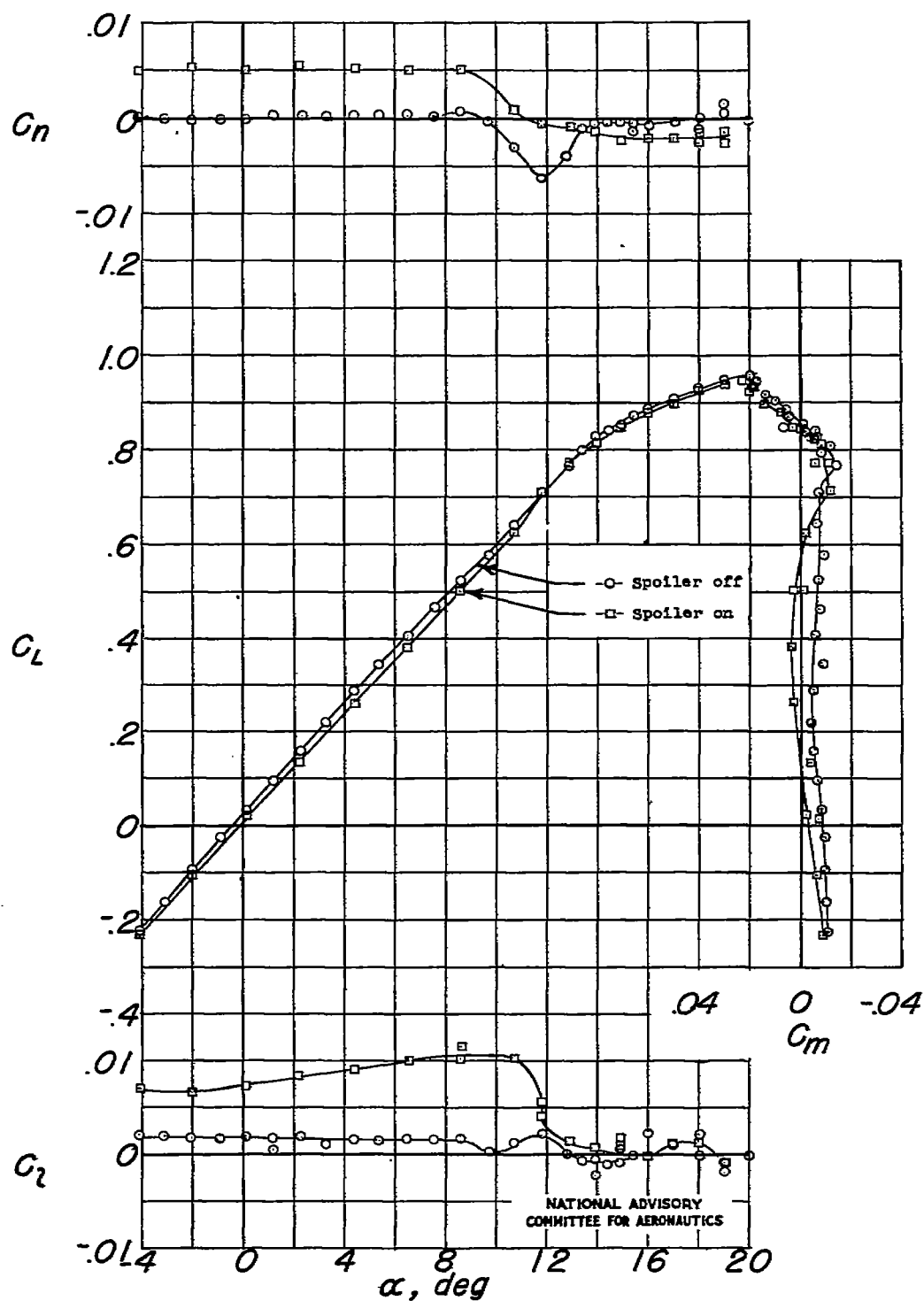


Figure 15.- Aerodynamic characteristics of 42° swept-back wing with spoiler. Leading edge rough; flaps off; $R = 5,300,000$; $\gamma = 0^\circ$.

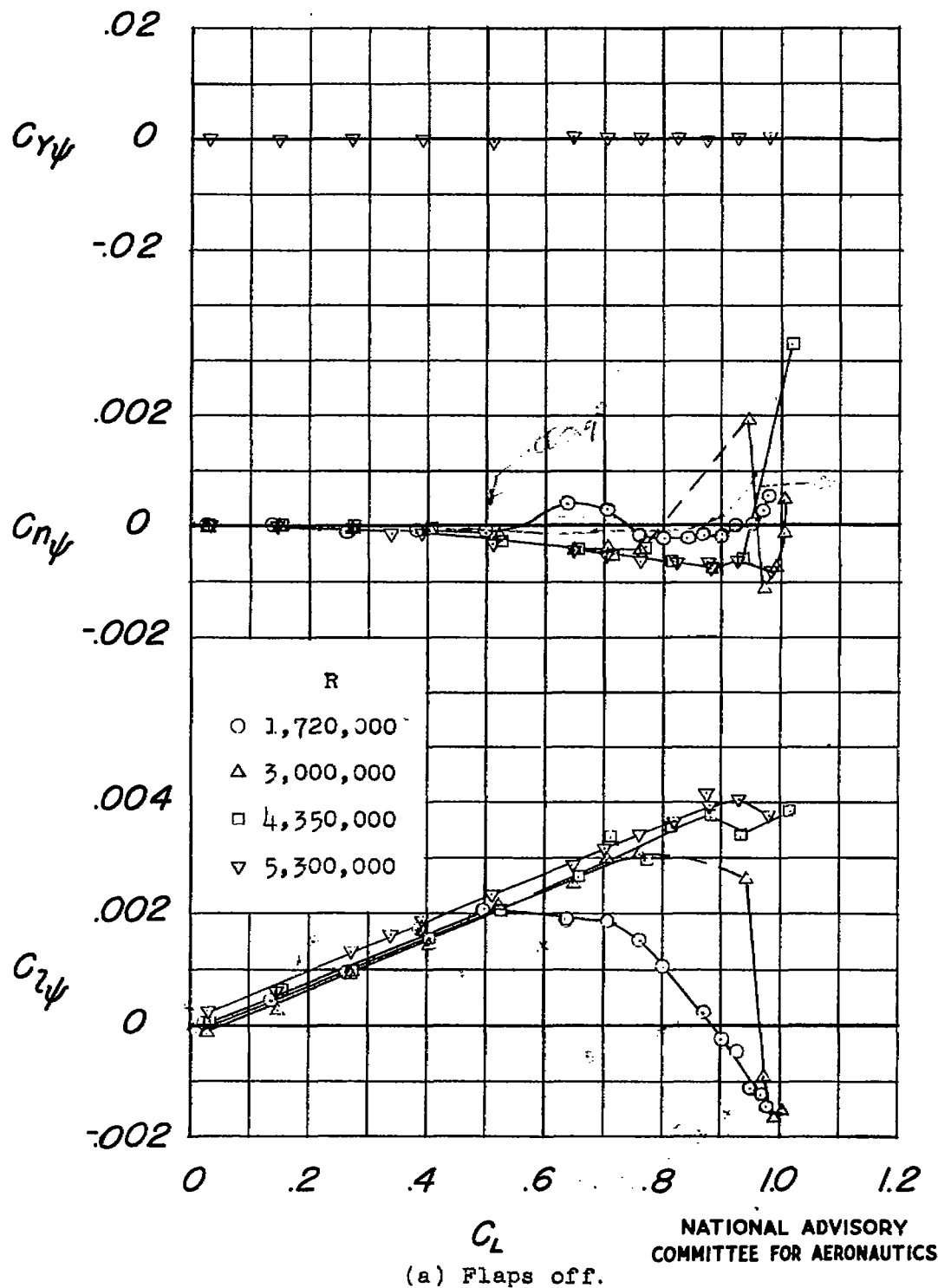
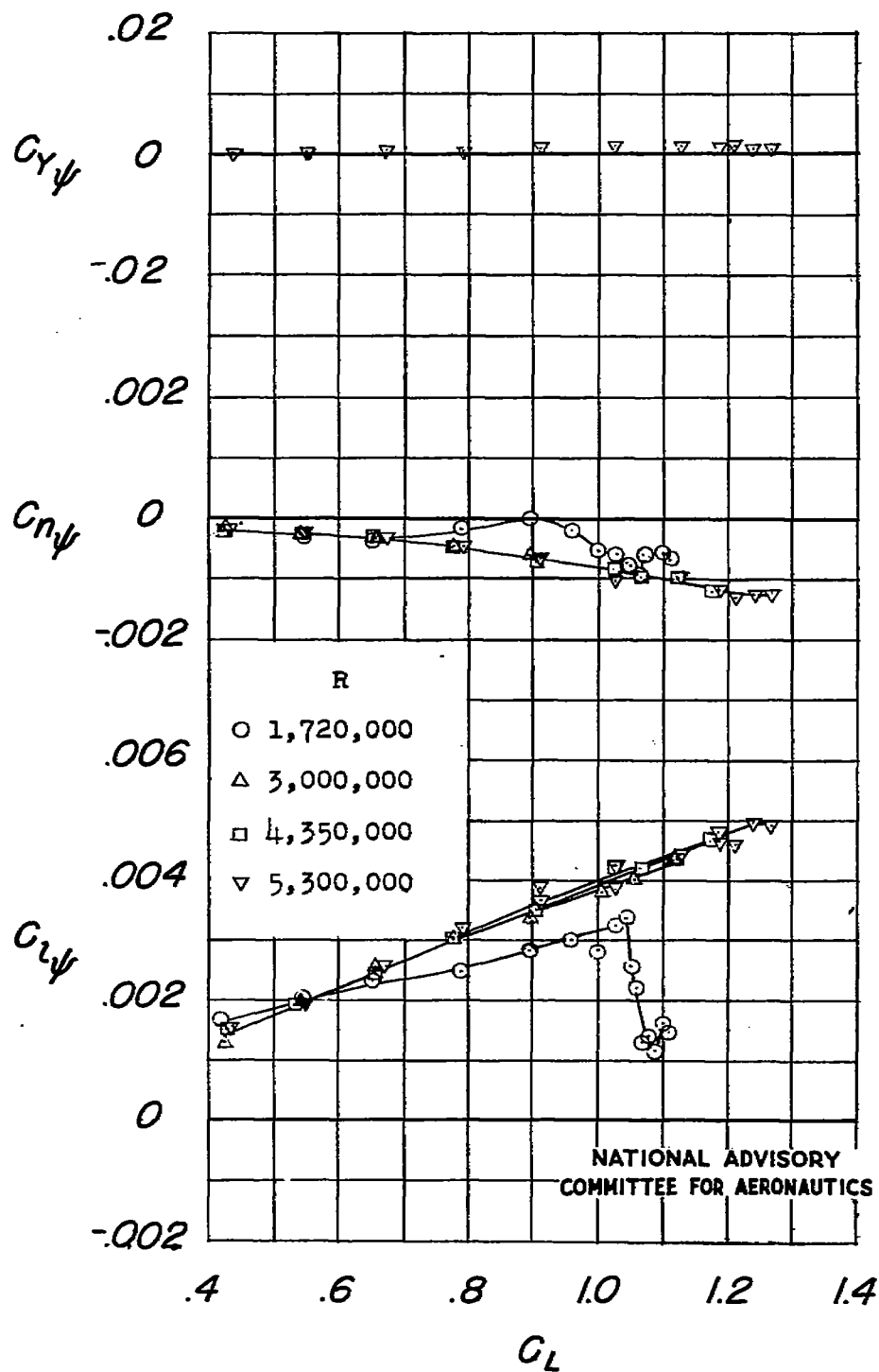


Figure 16.- Lateral-stability parameters of smooth wing at several values of Reynolds number.



(b) Flaps on.

Figure 16.- Concluded.

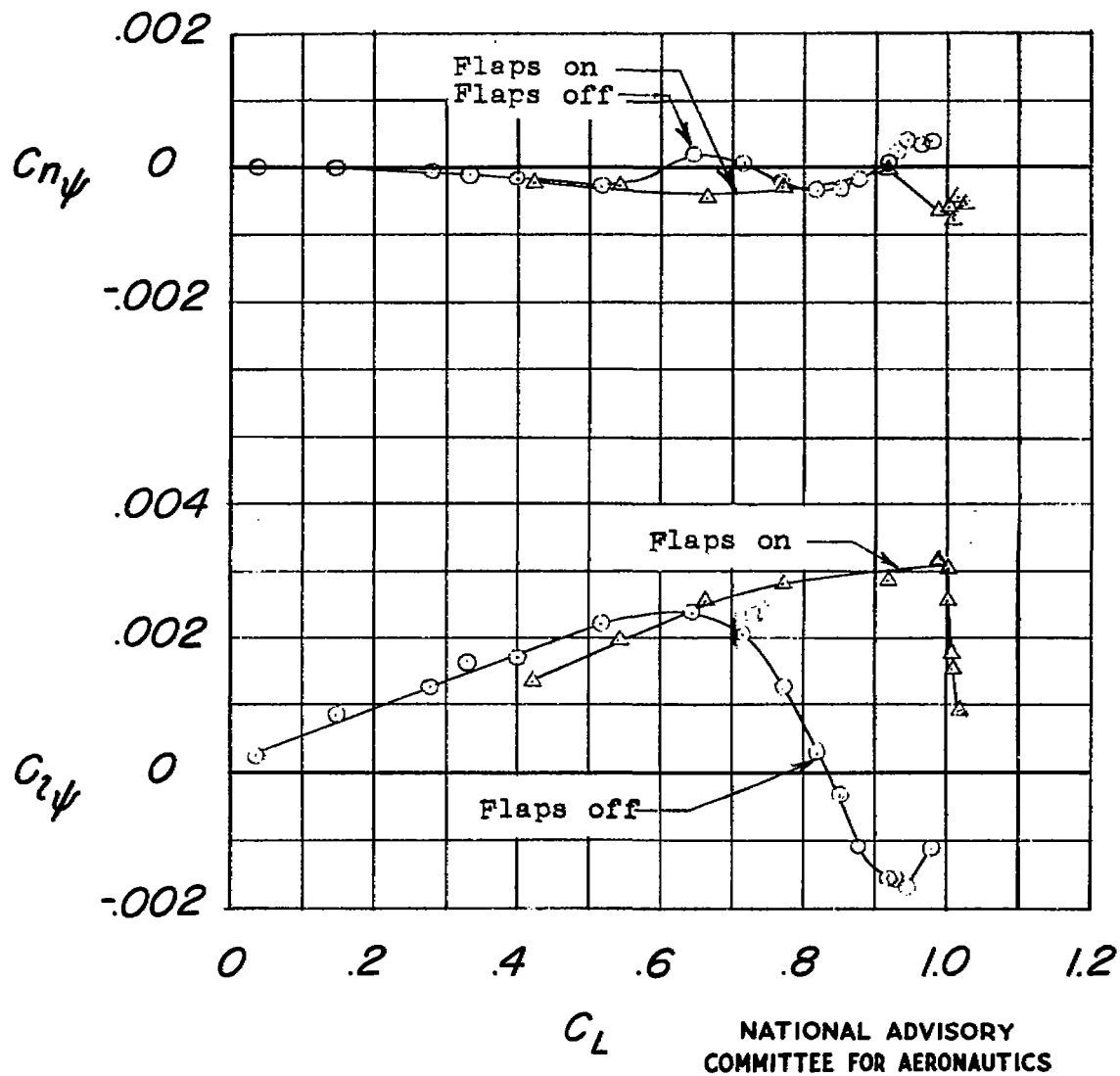


Figure 17.- Lateral-stability parameters of wing with leading-edge roughness. $R = 5,300,000$.

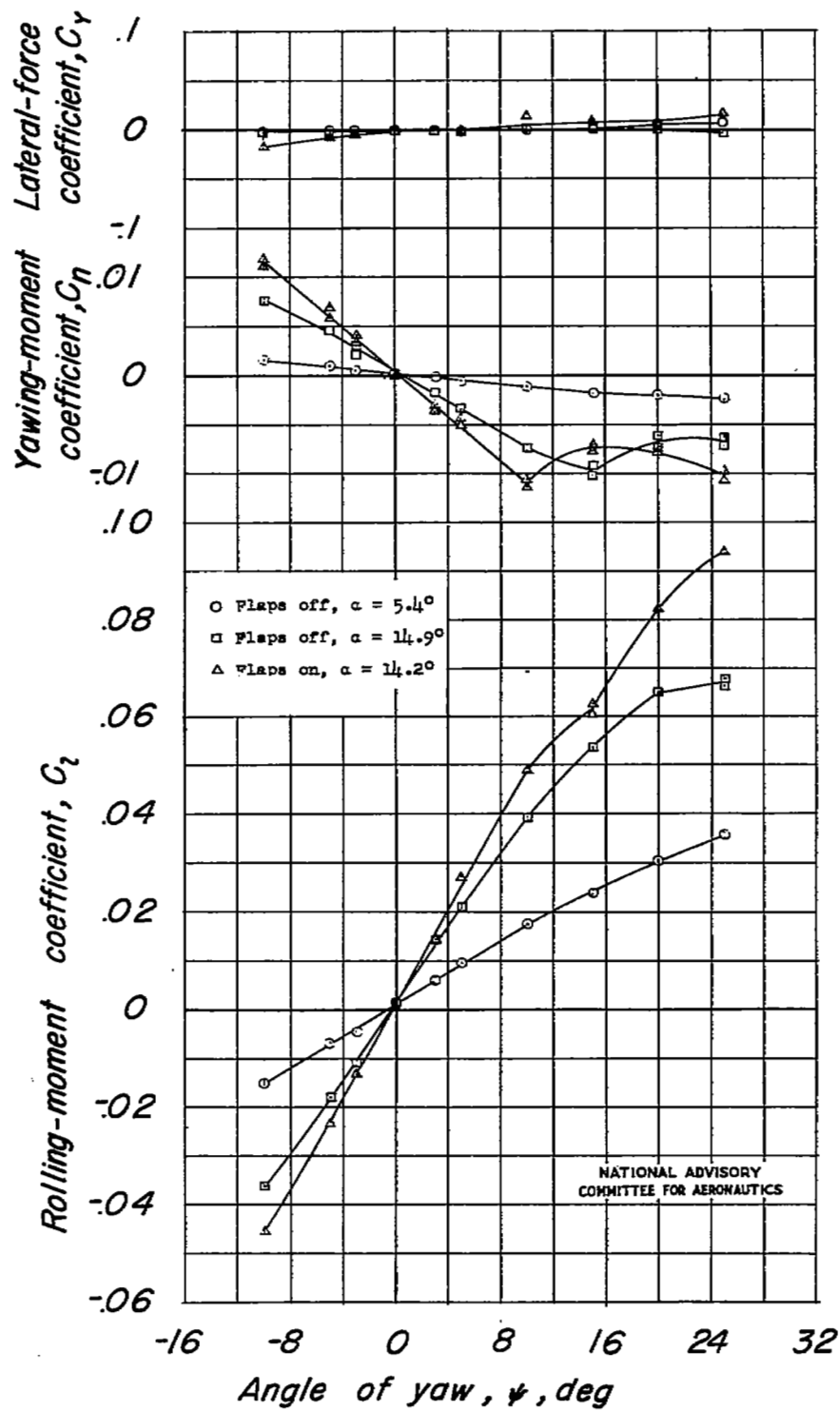
(a) C_l , C_n , C_y against ψ .Figure 18.- Aerodynamic characteristics in yaw of smooth wing. $R = 5,300,000$.

Fig. 18b

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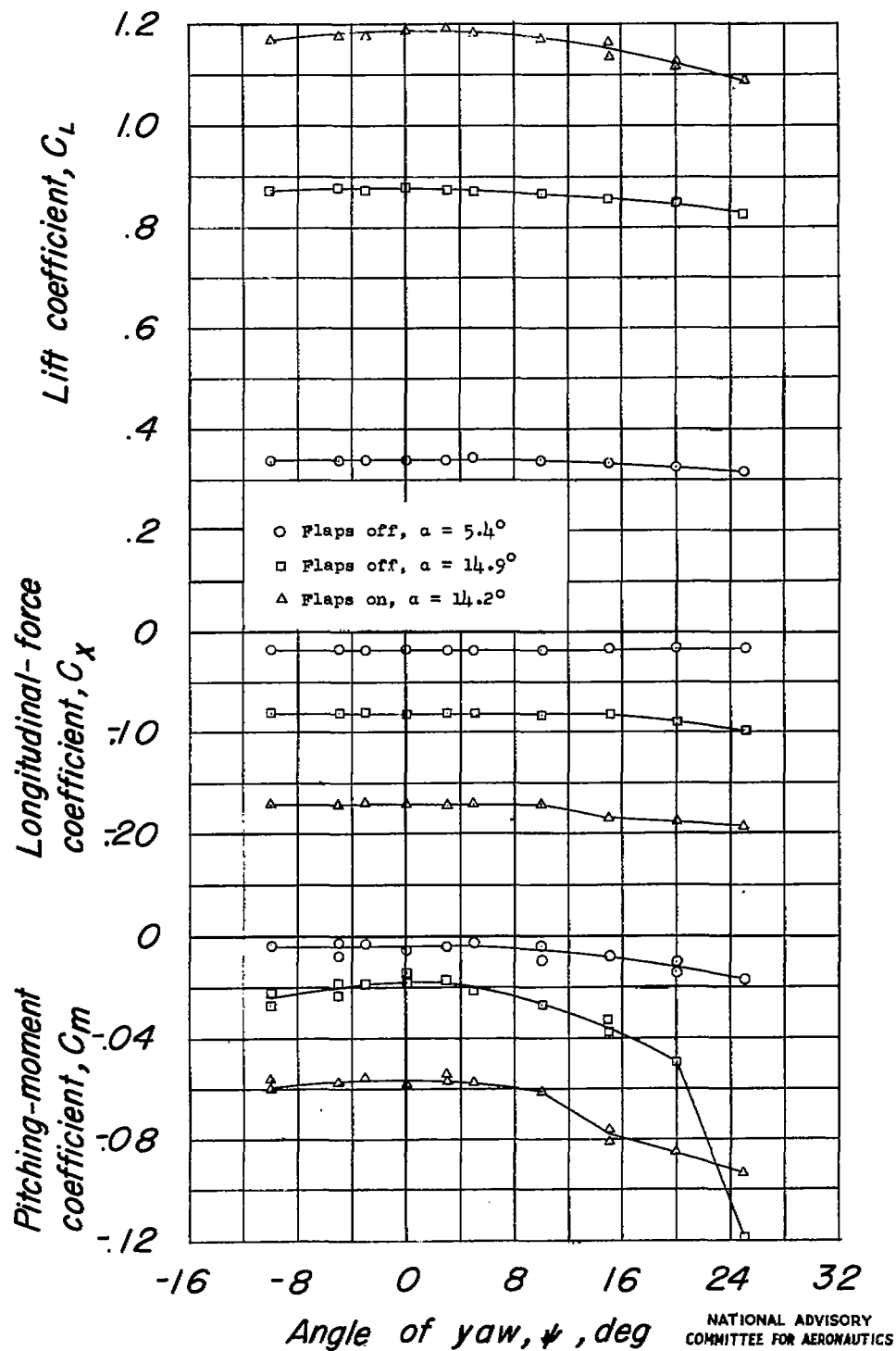
(b) C_m , C_X , C_L against ψ .

Figure 18.- Concluded.

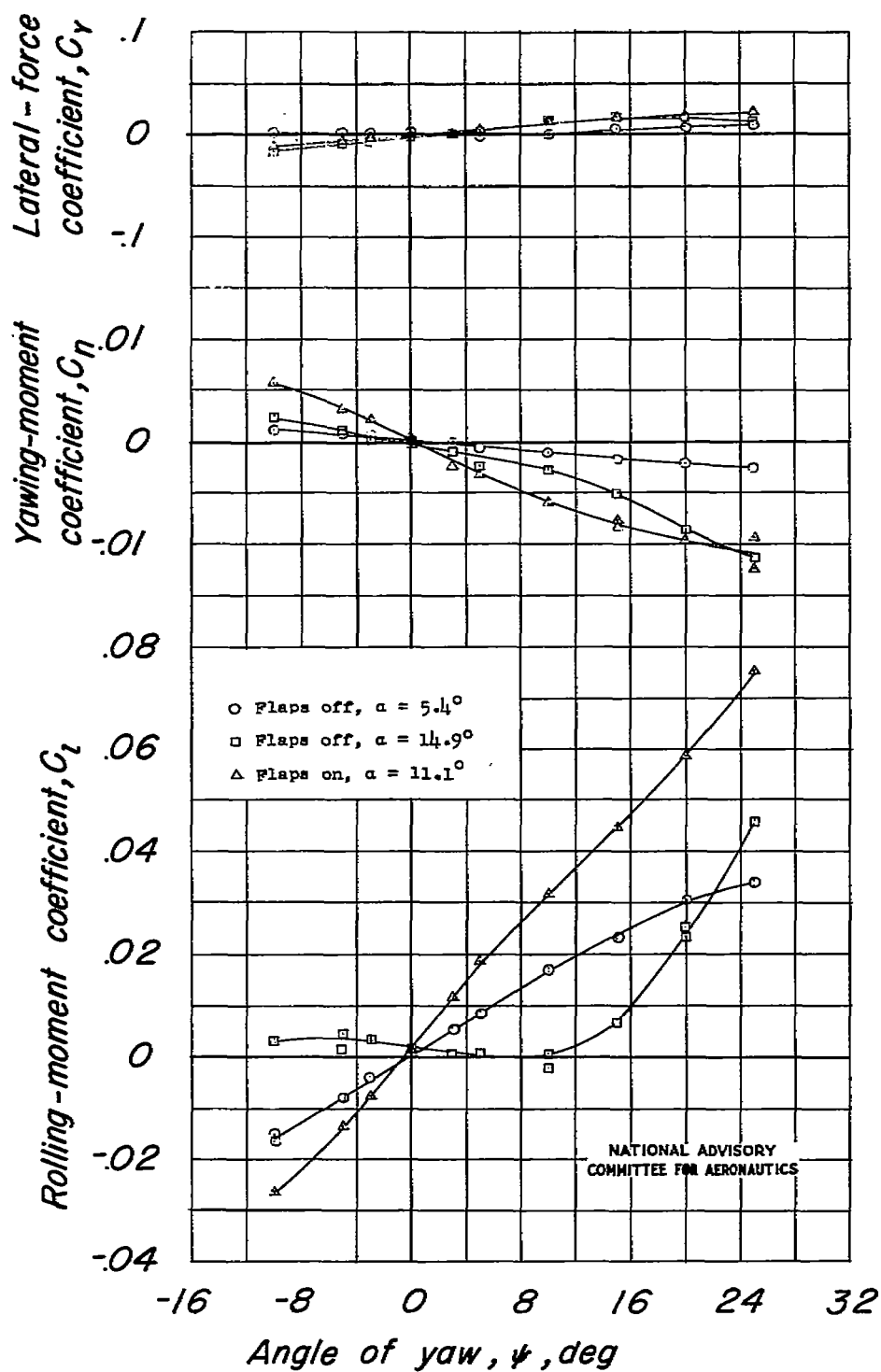
(a) C_l , C_n , C_Y against ψ .Figure 19.- Aerodynamic characteristics in yaw of wing with leading-edge roughness. $R = 5,500,000$.

Fig. 19b

NACA RM No. L7D14

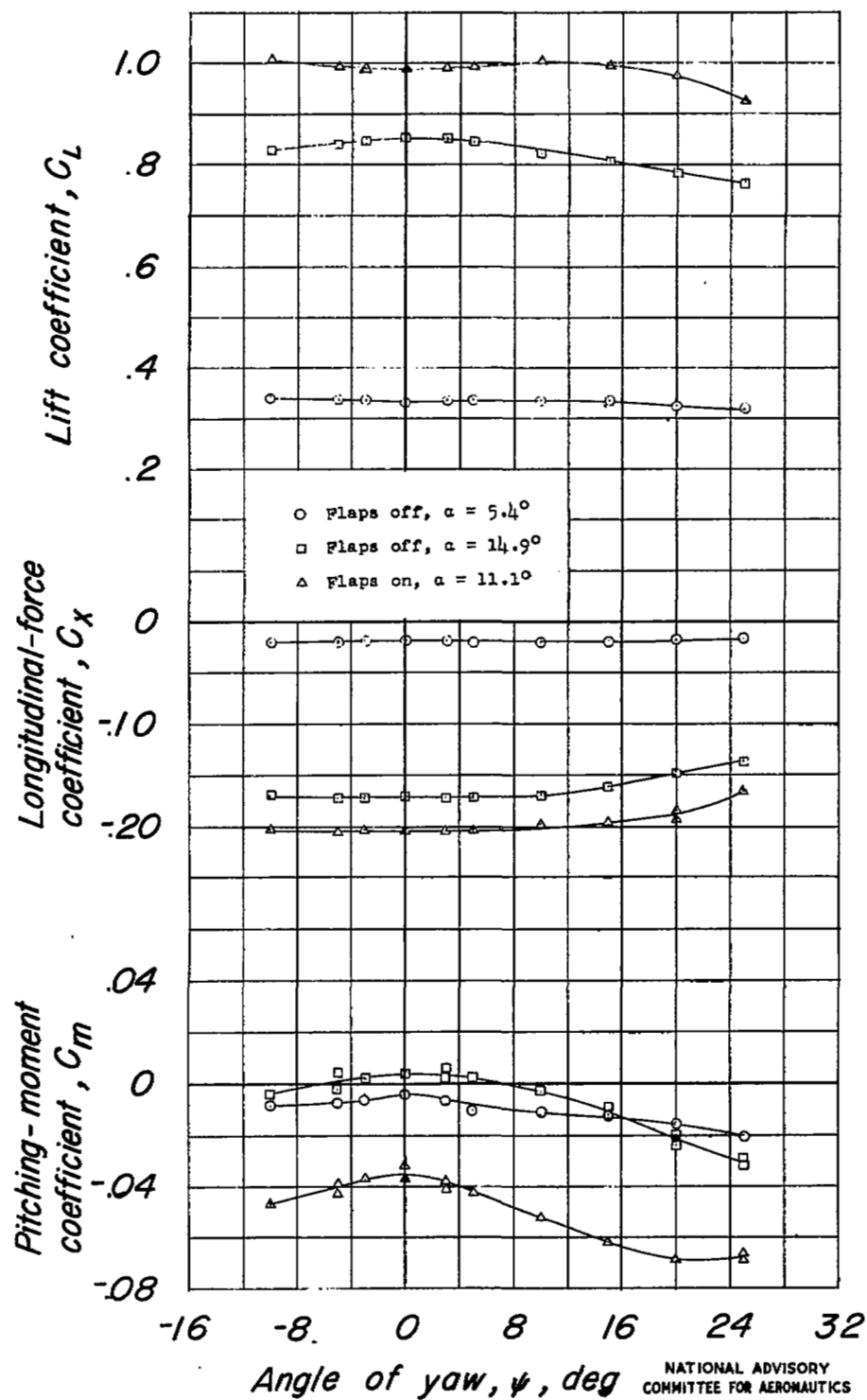
(b) C_m , C_X , C_L against ψ .

Figure 19.- Concluded.

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